

MAGNUS WESTGREN

Electronic Fetal Monitoring and Delivery of the Preterm Infant

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ELECTRONIC FETAL MONITORING AND DELIVERY OF THE PRETERM INFANT

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Abstract The present work studied electronic fetal monitoring of preterm pregnancies and the obstetric management of patients in preterm labor and delivery. The fetal heart rate (FHR) and fetal movements (FM) were investigated by a longitudinal study in normal, pregnant women from the 25th week of gestation until term. With advancing gestational age the mean R-R interval increased significantly and was accompanied by an increase of long- and short-term variability (computer analysis) until 31st-35th week of gestation. After the 30th week accelerations were concomitantly recorded at FM. Before that age the predominant FHR responses at FM were decelerations. It is concluded that account should be taken of the gestational age in the interpretation of the FHR recordings of immature fetuses. Electronic fetal monitoring and fetal acid-base balance were prospectively studied during preterm labor in 61 patients with an infant in vertex presentation. Tachycardia (43 %), decreased variability (39 %) and variable decelerations (61 %) were often recorded. Ominous fetal heart rate patterns were related to a low fetal scalp pH in a manner similar to that previously reported in studies of mature fetuses. Moderate variable decelerations were associated with fetal acidosis more frequently at lower gestational age. Intrapartum fetal acidosis (scalp pH < 7.25) was common (25 %), but occurred predominantly before the 34th week. Infants with intrapartum fetal acidosis had more neurological abnormalities in the neonatal period and a higher rate of neurodevelopmental disabilities than non-acidotic infants at a 2-years follow-up (Denver Developmental Standard test). The significance of the mode of delivery was investigated in three studies. Firstly, in an evaluation of the obstetric management of 72 singleton infants weighing less than 1 500 g revealed that autopsy findings of intraventricular hemorrhages were more frequent in vaginally delivered infants born in vertex presentation than in abdominally delivered infants. Secondly, in a paired matched control study of patients in preterm labor without additional complications 59 infants weighing less than 2 000 g born vaginally in vertex presentation were compared to 59 infants delivered by cesarean section. The mortality rate did not differ between the groups, but at a 18-24 months follow-up the rate of psychomotor retardation was significantly higher in the vaginal delivery group. These data suggest a potential adverse impact on the preterm fetus at vaginal vertex delivery. Thirdly, routine cesarean section at preterm breech delivery (< 36 weeks) was started in 1975. All infants born until 1977 were followed up prospectively for at least 1-5 years. The outcome in this group was compared with breech infants born vaginally in 1971-1974. After introduction of cesarean section the neonatal mortality was reduced from 14.6 % to 4.8 %, and at 1 year of age 24 % of those born vaginally had neurodevelopmental abnormalities compared with 2.5 % of those delivered by cesarean section. The implication of these findings for the obstetric management of patients in preterm labor and delivery are discussed.		
Key words Fetal monitoring, fetal distress, long-term variability, short-term variability, preterm delivery, prematurity, cesarean section, fetal acid-base balance, breech delivery, intraventricular hemorrhages, long-term follow-up, asphyxia neonatorum, cerebral palsy, psychomotor retardation.		
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Date 1983-02-23

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University Hospital, Lund, Sweden

ELECTRONIC FETAL MONITORING AND DELIVERY OF THE PRETERM INFANT

By
Magnus Westgren

1983

To strut before a wanton ambling nymph;
I, that am curtail'd of this fair proportion
Cheated of feature by disembling nature,
Deform'd, unfinish'd, sent before my time
Into this breathing world, scarce half made up,
And that so lamely and unfashionable
That dogs bark at me as I halt by them;

From The Tragedy of King Richard The Third
by William Shakespeare

(King Richard III was born preterm in
malpresentation the 2nd October 1452)



To Ninni and our sons
Carl and Axel

The present thesis is based on the following publications, which will be referred to by their Roman numerals.

- I. Ingemarsson I, Westgren M, Svenningsen NW.
Long-term follow-up of preterm infants in breech presentation delivered by caesarean section, a prospective study.
The Lancet ii:172, 1978.
- II. Westgren M, Ingemarsson I, Ahlström H, Lindroth M, Svenningsen NW.
Delivery and long-term outcome of very low birth weight infants.
Acta Obstet Gynecol Scand 61:25, 1982.
- III. Westgren M, Dolfin T, Halperin M, Milligan J, Shennan A, Svenningsen NW, Ingemarsson I.
Mode of delivery in the low birth weight fetus in vertex presentation. A paired controlled study with long-term follow-up.
Acta Obstet Gynecol Scand Accepted for publication, 1983.
- IV. Westgren M, Holmquist P, Svenningsen NW, Ingemarsson I.
Intrapartum fetal monitoring in preterm deliveries: Prospective study.
Obstet Gynecol 60:99, 1982.
- V. Westgren M, Holmquist P, Ingemarsson I, Svenningsen NW.
Intrapartum fetal acidosis in preterm infants. A prospective study in regard to fetal monitoring and long-term morbidity.
Obstet Gynecol Submitted for publication.
- VI. Westgren M, Nygren Å, Blohm R, Ingemarsson I.
Fetal heart rate, long- and short-term variability in relation to advancing gestational age. With special reference to fetal movements.
Am J Obstet Gynecol Submitted for publication.

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ABBREVIATIONS AND DEFINITIONS

CST = contraction stress test
CTG = cardiotocography
ECG = electrocardiogram
EFM = electronic fetal monitoring
FHR = fetal heart rate
FM = fetal movement
IVH = intraventricular hemorrhage
NICU = neonatal intensive care unit
NST = nonstress test
SEH = subependymal hemorrhage
SGA = small for gestational age
VLBW = very low birth weight

Low birth weight: less than 2 500 g.

Very low birth weight: less than 1 500 g.

Preterm: delivered before 36 completed weeks

R-R interval: time period between successive R waves of the fetal ECG.

Small for gestational age: infants whose birth weight was > 2 SD below the mean, from the Swedish standard curves.

Swedish perinatal statistics include: for livebirths (evidence of life i.e. breathing, heartbeats, pulsation of the umbilical cord or definite movements of voluntary muscles) all infants that die, regardless of gestational age in the perinatal period. For stillbirths, 28 completed weeks or body length ≥ 35 cm (crown-heel).

INTRODUCTION

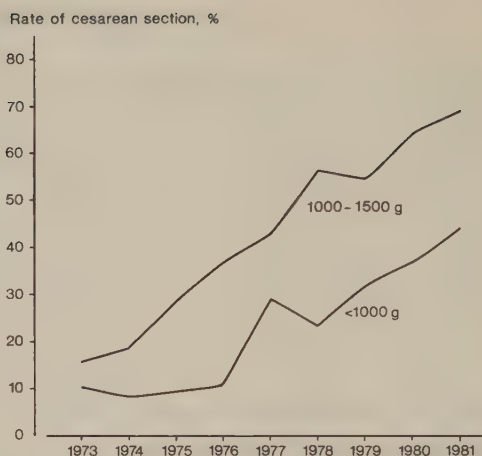
Over the past decades, improved capability of neonatal care has significantly bettered the prognosis for preterm infants. Neonatal units can now achieve survival rates of about 90 % for the 1000-1500 g group and over 70 % for the 750-1000 g group of infants (Stewart et al 1981, Driscoll et al 1982, Svenningsen 1982). Nevertheless, preterm delivery remains the major contributing cause of perinatal mortality and morbidity (Rush et al 1976, Karlberg & Ericsson 1979, Lagergren 1981).

Concomitantly with the development of neonatal medicine, obstetric care has changed from an inactive to a more active attitude. New methods have been introduced for monitoring fetal growth, well-being and maturation as well as new principles for labor inhibition and induction of lung maturity. A short review is useful in order to provide a perspective of the current status.

In the 1960s and early 1970s the obstetric care of patients in preterm labor was characterized by a primarily conservative attitude towards intervention on fetal indications. Most obstetricians were reluctant to consider such active measures as cesarean section, since, at the time, the prognosis for preterm infants was poor (Drillen 1961, Lubchenko et al 1963). In addition, Usher et al in 1964 postulated that cesarean section was associated with an increased risk for respiratory distress syndrome. Their result and similar findings by Dunn et al (1974) were for many years used as an argument for a nonintervention policy. This attitude was predominant until the mid 1970s (Kubli et al 1976).

In 1974 Stewart and Reynold were the first to question the passive non-intervention course. Their results showed a better prognosis for very low birth weight (VLBW) infants after abdominal delivery. They suggested a more active and supporting approach for patients in early preterm labor. At the same time several investigators reported improved long-term outcome for preterm infants (Davies & Tizard 1975, Hagberg et al 1975). These reports formed a basis for a changing attitude in favor of a more active obstetric management of preterm labor and delivery. Consequently, the use of cesarean section on fetal indications increased thereafter. For instance, in Sweden from 1973 to 1981 the rate of cesarean section for infants weighing 1000 - 1500 g increased from 16 % to 69 % and for infants weighing less than 1000 g from 10 % to 44 % (Fig. 1). It is reasonable to suggest that until the mid 1970s this rise can be referred to maternal indications, whereas ex-

Fig. 1. Rate of cesarean section in patients delivered from infants weighing 1 000-1 500 g and less than 1 000 g in Sweden, 1973-1981 (Ericsson A 1983, National Board of Health and Welfare, Stockholm Sweden).



tended fetal indications contribute later to the increase.

In spite of more aggressive obstetric management of preterm labor, the intrapartum surveillance of the preterm fetus remained disregarded. Continuous electronic fetal monitoring (EFM) and fetal pH assessments were introduced in the late 1960s, and soon these methods became widely accepted. However, it was common to neglect patients in preterm labor (Paul & Hon 1974, Neutra et al 1978), which is still prevailing for very preterm deliveries (Paul et al 1979). Although trend analysis indicated that EFM should be most useful in preterm deliveries (Paul et al 1977, Ingemarsson et al 1981), few studies on this matter have been carried out.

It is difficult to evaluate to what extent minor or major changes in obstetric care contribute to the improved prognosis for preterm infants. Various factors render it hard to evaluate the impact; a sufficient number of cases is often difficult to obtain, e.g. less than 200 infants weighing less than 1 000 g are born each year in Sweden. The obstetric intervention is often performed owing to an additional complication which could *per se* influence the results. Improvements in the standard of neonatal care can also influence the results. Furthermore, long-term follow-up studies are often required to assess the quality of the care. These circumstances probably explain why relatively few investigations have been performed on the obstetric management of preterm delivery.

The present status of perinatal care is a result of close cooperation between obstetricians and neonatologists. The survival rate of preterm infants has steadily increased (Fig. 2). The morbidity in surviving infants



Fig. 2. Rate of perinatal survivors in per cent of liveborn infants weighing 1 000-1 500 g and less than 1 000 g in Sweden, 1973-1981 (Origin as in figure 1).

is the major concern today. Recent reports on infants with residual problems have emphasized the predominance of those with clinical evidence of birth asphyxia, intraventricular hemorrhages or severe respiratory failure (Fitzhardinge et al 1978, Stewart et al 1978, Hagberg et al 1982). Some of these complications could possibly be prevented by optimal obstetric care. A thorough evaluation of the obstetric management of the patient in preterm labor and delivery is therefore required.

AIMS OF THE INVESTIGATION

1. To study various parameters of the fetal heart rate (FHR) in relation to increasing maturity in normal pregnancies from the 25th week of gestation until term.
2. To study the frequency of different FHR findings in preterm vertex deliveries, and to investigate the relationship between these FHR patterns and fetal acid-base status.
3. To study short-term and long-term fetal outcome in relation to fetal acid-base status in preterm vertex deliveries.
4. To study short-term and long-term fetal outcome in relation to mode of delivery at vertex and breech presentation in preterm deliveries.

MATERIAL AND METHODS

THE CLINICS INVOLVED, A SHORT DESCRIPTION

The Department of Obstetrics and Gynecology, Lund University Hospital, serves the city of Lund and a major part of Malmöhus County which is the most densely populated area in Sweden. All deliveries within the area take place in the Department. The annual birth rate is about 3 000. The clinic is the referral centre for selected high risk pregnancies for another 5 000 livebirths as well.

According to the prevailing Swedish medical system all pregnant women are routinely checked up at the Maternal Health Care Centres during pregnancy; every month up to the 20th week, every other week up to the 35th week and thereafter weekly. All deliveries are supervised and managed by the hospital staff obstetricians. Every preterm newborn is taken care of by the hospital staff neonatologists and treated in the neonatal intensive care unit (NICU), adjacent to the delivery ward. Thus, the perinatal management is carried out in close collaboration between obstetricians and neonatologists and has a high degree of homogeneity.

The Department of Obstetrics and Gynecology, Community Hospital, Helsingborg serves the city of Helsingborg and the surrounding district. The annual birth rate is about 2 200. The Helsingborg district borders on the area of Lund, and there is a close cooperation between these departments.

The Perinatal Unit, Women's College Hospital, Toronto is the perinatal referral centre for the State of Ontario. The inborn population is about 3 200 livebirths per year. This clinic covers a population of 15-18 000 annual livebirths in respect to high risk pregnancies.

CLINICAL MATERIAL AND METHODS

Paper 1. This study includes all singleton pregnancies with infants in breech presentation admitted to the Department in Lund from January 1, 1971 to February 1, 1977, and delivered before the 37th week of gestation. A prospective study began on January 1, 1975, with routine cesarean section as method for delivery. Until February 1, 1977, 42 preterm infants were delivered, all by cesarean section. For comparison, the records of 48 infants (all vaginally delivered) born January 1, 1971 to December 31, 1974 were evaluated retrospectively. All surviving infants have participated in

a scheduled follow-up for at least 1 year.

Paper II. All singleton infants weighing less than 1 500 g born from January 1, 1975 to December 31, 1978 at the Department in Lund were studied. During the period 12 773 singleton infants were born. Seventy-two of these infants (5.6 ‰) weighed less than 1 500 g. The fetal and neonatal outcome was related to the mode of delivery. All surviving infants have participated in a scheduled follow-up for at least 2 years.

Paper III. In a paired controlled study 59 infants, weighing less than 2 000 g in vertex presentation delivered vaginally, were compared to 59 infants delivered by cesarean section. The material was collected from the birth records of all deliveries from 1975 to 1980 in the Departments in Lund, Helsingborg and Toronto (in total 49 000 deliveries). Retrospective review was undertaken of all antepartum and intrapartum records of mothers delivered by cesarean section of an infant weighing less than 2 000 g. Those delivered by cesarean section, owing to indications not considered to influence the outcome, were identified. Matched controls delivered vaginally were selected. All pairs fulfilled the following criteria: delivery in the same gestational week, birth weight within ± 200 g, delivery in the same delivery ward, neonatal treatment in the same NICU and delivery date within the preceding or following 6 months. These criteria were fulfilled by 59 pairs. All surviving infants, except 7 in Canada were reexamined at 5-6, 9-11 and 18-24 months of age regarding morbidity and neurodevelopmental handicaps.

Papers IV-V. Fetal acid-base balance and FHR were studied prospectively in 61 singleton infants in vertex presentation born at the Department in Lund before the 37th week of gestation in 1979 and 1980. All mothers had an uneventful pregnancy before admission to the delivery ward. Thus, there were no additional maternal or fetal complications. During labor all patients were monitored according to a standardized program. Electronic fetal monitoring via a fetal scalp electrode was started when the cervix was effaced and dilated at least 4 cm. Fetal scalp pH was measured routinely at 5 cm and at full cervical dilatation. At birth acid-base status was measured in umbilical artery. After delivery, the neonatologist decided the need for resuscitation and determined the Apgar scores. Acid-base status was measured repeatedly during the initial 30 minutes. The infant was thereafter transferred to the NICU for treatment, as described earlier

(Lindroth et al 1980). After discharge from NICU all infants were reexamined at 3, 7, 12 and 24 months of age with neurodevelopmental examinations (Denver Developmental Standard test) by either of the partaking pediatricians.

Paper VI. Four women with an uneventful pregnancy were followed weekly from the 25th week of gestation until term with abdominal ECG recordings of 40 min duration under standardized conditions. Maternal perception of fetal movements (FM) during the recordings was registered. All data regarding FHR and FM were stored on an analogous FM-tape recorder for further transference into a computer system. Correction for known errors and alterations in FHR was performed before any calculation were made (see software paper VI). The computer calculated the mean heart interval, long-term variability and short-term variability. The long-term variability was calculated as the standard deviation of the R-R intervals (Dalton et al 1977) and the short-term variability as the standard deviation of the interval differences (Wheeler et al 1979). The frequency of accelerations (amplitude more than 15 beats and duration longer than 15 seconds) and decelerations (loss of more than 15 beats and duration longer than 15 seconds) at FM was also evaluated. All parameters were assessed in relation to the stage of fetal development.

STATISTICAL METHODS

Papers I, IV, V and VI used the χ^2 test and/or Student's t-test for statistical evaluation. Paper III used Fisher's exact probability test for independent groups (Fleiss 1973).

RESULTS AND DISCUSSION

PRETERM BREECH DELIVERY

The frequency of breech presentation declines with advancing gestational age from about 30 % in the 30th week of gestation to about 3.5 % at term (Scheer & Nubar 1976). Approximately one fifth of all preterm deliveries involves infants in breech presentation.

It has long been recognized that the preterm infant presenting by the breech runs an increased risk compared to other presentations at vaginal delivery (Brander 1936, Galloway et al 1967, Kauppila 1975). Thus, vaginal delivery of the preterm breech has been associated with a high percentage of footling (Goldenberg & Nelson 1977, Karp et al 1979), a subsequent greater likelihood of cord accidents (Kauppila 1975), a tendency for the aftercoming head to be entrapped in the incompletely dilated cervix (Galloway et al 1967) and an increased risk for asphyxia (Rovinsky et al 1973). Studies, including autopsy findings (Kauppila 1975, Fianu 1976), revealed conspicuously high rates of injuries which are assumed to be directly related to the method of delivery such as tentorial rupture and injuries on the abdominal viscera. Moreover, asphyxia due to cord compression or a difficult delivery of the fetal head resulting in osteodiasis (Wigglesworth & Husemeyer 1977) predispose to intraventricular hemorrhages (IVH) (Pape & Wigglesworth 1979).

Concern of the high mortality rate associated with preterm breech deliveries caused several authors to suggest that the fetal outcome could be improved by alternative obstetric management. Crawford (1974) advocated the use of conduction analgesia for preterm vaginal breech delivery. More recently Milner (1975) demonstrated that the use of forceps on the aftercoming head significantly reduced the mortality rate in preterm breech infants. Several other authors (Rovinsky et al 1973, Cruikshank & Pitkin 1977) stressed the value of EFM and blood sampling in these deliveries. However, the most severe complication of preterm breech at vaginal delivery - entrapment of the fetal head in an incompletely dilated cervix - can possibly not be eliminated by these measures. This has led several authors to advocate that cesarean section is the preferable delivery route for the preterm infant in breech presentation.

Paper I deals with a prospective study of routine cesarean section at preterm breech delivery. From 1975 to 1977, 42 preterm breech infants

delivered by cesarean section before the 37th week of gestational age were followed up prospectively for at least 12 months. The outcome of this group was compared with that of all 48 preterm breech infants delivered vaginally in 1971-1974, before the introduction of routine cesarean section. After introduction of abdominal delivery in preterm breeches the neonatal mortality was reduced from 14.6 to 4.8 %. Cerebral spinal fluid hemorrhages occurred more often in vaginally delivered infants (39 %) than in infants delivered by cesarean section (9 %). At follow-up at 1-5 years of age 24 % of the vaginally delivered infants and 2.5 % of those delivered by cesarean section had developmental or neurological sequelae ($p < 0.01$).

Randomized assignments to cesarean section and vaginal delivery are difficult to obtain. In Paper I a prospective study from one period was compared to a retrospective study from another. This factor could introduce a bias in favor of those delivered in the later period due to improved obstetric and neonatal care. The degree of the influence of this effect on the results in Paper I is impossible to evaluate retrospectively but the occurrence of tentorial rupture, subdural hematoma and spinal cord injuries in vaginally born infants indicates that the risk of birth trauma is high at vaginal delivery.

Several other papers concerning the obstetric management of the preterm breech delivery have been published in recent years (Table I). Various factors make it difficult to assess the data of these studies. The studies were performed retrospectively. The cesarean section was in most studies carried out owing to other obstetric complications than preterm breech presentation. In most series, detailed autopsy findings are not given and several studies contain only a small or an unequal number of cases. In view of the limitation and the differences between these materials it is surprising how well the results agree: Infants expected to weigh less than 1 500 g or born before the 33rd week of gestation survived more frequently after cesarean section than did those delivered vaginally, while in infants weighing more than 1 500 g there were no significant differences in survival rate between vaginally and abdominally delivered infants. The poor prognosis for very preterm breeches at vaginal delivery is confirmed in a recently published study by Lamont et al (1983), where they demonstrated a 55 % incidence of IVH diagnosed by ultrasonography in vaginally born breeches compared to 13 % in cesarean section born infants in the 26th-33rd week of gestation.

Table I. Mortality at preterm breech delivery. Vaginal delivery vs cesarean section in relation to birth weight or gestational age.

Source	Years of birth and weight or age of infants		Mortality			
			< 1500 g		> 1500 g	
			vaginal delivery	cesarean section	vaginal delivery	cesarean section
Goldenberg & Nelson (1977)	1970-1975 < 2500 g	PNM*	49/64 (77 %)	13/23 (57 %)	2/54 (4 %)	11/133 (8 %)
Bowes et al (1979 b)	1970-1977 501-2500 g	NNM*	39/57 (68 %)	3/12 (25 %)	2/62 (3 %)	0/20 (0 %)
Duenhoelter et al (1979)	1972-1977 1000-2499 g	NNM	5/9 (55 %)	0/9 (0 %)	2/35 (6 %)	1/35 (3 %)
Karp et al (1979)	1970-1975 < 2500 g	PNM*	6/15 (40 %)	3/5 (60 %)	2/33 (6 %)	0/13 (0 %)
Mann & Gallant (1979)	Not given 500-2500 g	NNM	34/44 (77 %)	7/15 (47 %)	3/34 (9 %)	1/9 (11 %)
Woods (1979)	1970-1975 1000-2499 g	NNM	10/16 (63 %)	1/4 (25 %)	4/39 (10 %)	2/18 (11 %)
Kauppila et al (1981)	1967-1976 1000-2499 g	NNM	32/43 (74 %)	1/7 (14 %)	7/68 (10 %)	1/45 (2 %)
Nisell et al (1981)	1972-1978 < 2500 g	PNM	9/36 (25 %)	0/6 (0 %)	0/30 (0 %)	0/26 (0 %)
			< 32 weeks		33-37 weeks	
Geirsson et al (1982)	1976-1977 < 37 weeks	NNM	14/18 (78 %)	0/2 (0 %)	2/9 (22 %)	0/6 (0 %)

PNM = perinatal mortality (0-7 days), NNM = neonatal mortality (0-28 days)

* Corrected mortality, exclusive of infants dying of major congenital anomalies, erythroblastosis fetalis etc.

In evaluating changes in obstetric care the morbidity must also be considered. Unfortunately, only a few of the above mentioned studies present results concerning follow-up data. Woods (1979) in a follow-up of 38 of 60 surviving neonates found only 1 infant with neurological sequelae. Nisell et al (1981) followed 21 infants with reduced Apgar scores in their series of 98 infants. At follow-up 2 vaginally born and 1 cesarean section born infant suffered from persistent neurological sequelae. Besides Paper I there is, to my knowledge, only one study available where complete follow-up results are presented. In a comparison of two different periods, 1973-1974 and 1979-1980, Kendall and Hommers (1981) and more recently Cox et al (1982) present follow-up data of preterm infants born in breech presentation. The cesarean section rate was in the first period 24 % and in the latter period 48 %. The mortality was reduced from 29 % to 15 %, but the handicap rate in survivors increased from 4.7 % in the first period to

21.9 % in the latter period. Thus, the increasing survival rate in their study was accompanied with an increased morbidity rate. However, the cesarean section in their study was carried out due to obstetric pathology and not to the sole indication of malpresentation. The different cesarean section rates in the periods indicate that they were hardly comparable in respect to antenatal complications. E.g. 8 of 9 in the latter period abdominally delivered infants who later developed neurological abnormalities had severe antenatal complications. Moreover, the authors themselves suggest that the increased handicap rate could reflect the introduction of new methods of intensive care for the newborns, i.e. in 1978-1980 of 8 infants weighing less than 1 500 g who were ventilated, 5 died and 2 had neurological abnormalities at the follow-up. Nevertheless, their results differ considerably from ours where the introduction of general cesarean section was followed by a marked fall in both mortality and morbidity.

Different recommendations for the obstetrical management of the preterm breech delivery have been proposed. Karp et al (1979) and Woods (1979) claim that the management of the low birth weight breech presentation should be individualized and that cesarean section should be reserved for the VLBW preterm infant presented by footling. However, their series are too small to permit such a conclusion and the mortality rate in vaginally delivered infants weighing less than 1 500 g in their studies is considerably higher than abdominally delivered infants in the same weight classes in the other materials. Bowes et al (1979 b), Mann and Gallant (1979), Kauppila et al (1981) and Nisell et al (1981) suggest that abdominal delivery is preferable in preterm breech infants with an expected birth weight of less than 1 500 g and that infants with a birth weight exceeding 1 500 g do well with vaginal delivery. As Goldenberg and Nelson (1977), Duenholter et al (1979) and Geirsson et al (1982) we have advocated routine cesarean section in Paper I at impending preterm breech delivery.

It is an open question if there is need for cesarean section for infants weighing more than 1 500 g or born in the 33rd-36th week of gestation. At the follow-up in Paper I, 5 out of 10 infants with neurological sequelae after vaginal delivery were born in these weeks of gestation. Similarly the other studies with follow-up results (Woods 1979, Nisell et al 1981, Cox et al 1982) list infants with neurological sequelae after vaginal delivery in these weeks of gestation. Furthermore, a number of the previously mentioned studies (Karp et al 1979, Woods 1979, Kauppila et al 1981) recommending cesarean section only for VLBW breeches, list typical delivery

related complications such as entrapment of the fetal head, cord prolaps and intracranial hemorrhages with tentorial tear also in infants born in the 33rd-36th week of gestation. Such delivery related complications are not accepted in term breeches. Why should they then be accepted in the 33rd-36th week of gestation? Brenner et al (1974) demonstrated in a study of 1 016 breech deliveries that it was in fact in the period of 33rd-36th week and not later in pregnancy that a measurable advantage could be ascribed to abdominal delivery. Thus, conflicting results regarding the preferable mode of delivery in preterm breeches in weeks 33-36 have been presented. Further prospective randomized studies with long term follow-up are required to settle this question.

The lower limit of gestational age or birthweight, when a cesarean section should be performed due to fetal indications, is discussed below (see Preterm vertex delivery). In planning cesarean section at impending preterm breech delivery it is of importance for the obstetrician to keep in mind the relatively high risk of congenital malformations among these infants (Brenner et al 1974). Ultrasonic scanning is recommended as a routine procedure prior to operative intervention.

In conclusion, in preterm breech delivery prior to the 33rd week of gestation cesarean section appears to be associated with a better infant outcome than vaginal delivery. The value of routine cesarean section from the 33rd to the 36th week of gestation remains debatable.

PRETERM VERTEX DELIVERY

There is a relatively extensive documentation of the obstetric management of the preterm breech but there are far less reports of the optimal management of the preterm fetus in vertex presentation. This seems inconsequent since many of the problems the preterm infant is confronted with in labor are related not only to the presentation but to the physiological characteristics of these infants. The soft cranium of the preterm infant offers less resistance to the compressions than the skull of a term infant (Kriewall & McPherson 1981). The moulding of the head in the second stage of labor may result in tearing of subependymal veins and cause subependymal hemorrhages (SEH) and IVH (Towbin & Turner 1978). Moreover, the oxygen carrying capacity of the very preterm fetus is low owing to a low hemoglobin concentration (Maxwell 1980) and the energy stores of fat and of liver glycogen are limited and may be insufficient to meet the demands at intra-

partum stress (Shelley 1973). Thus, it seems that the preterm infants, especially those born before the 33rd week of gestation or weighing less than 1 500 g, are less able than term fetuses to withstand the stress of labor.

Up till now most obstetricians have managed the preterm vertex delivery according to the same principles as for term labor. In order to avoid unnecessary trauma to the fetal head a routinely performed episiotomy is widely accepted. Moreover, some obstetricians advocate the use of low outlet forceps to protect the fetal head from compression of the vagina (Bishop et al 1965, Bowes et al 1979 a, Bühler & Roemer 1982). Owing to the moulding of the fetal skull the utilization of vacuum extraction has been discarded (Rösemann 1969). Cesarean section is only considered at signs of maternal or fetal distress but not at preterm vertex presentation as such.

Paper II deals with a population of patients giving birth to VLBW singleton infants who had been managed according to these principles. In 29 of the 72 patients (40 %) there was no additional obstetric complication and the fetus was in vertex presentation allowing a vaginal delivery. The neonatal mortality did not differ between the vaginally and the abdominally delivered infants. However, the autopsy findings differed considerably. Two of 11 infants who died in the cesarean section group had intracranial hemorrhages compared to 6 of 8 dead infants in the vaginal delivery group. At a 2-5 years follow-up 3 of 21 surviving infants in the vaginally delivered group had cerebral palsy and 1 retrolentatal fibroplasia. Two of 32 surviving infants in the cesarean section group were moderately psychomotor retarded. The results thus indicate a poorer outcome in infants born vaginally in vertex presentation than in cesarean section born infants.

Several studies reporting similar results with a favorable prognosis for cesarean section born preterm infants compared to vaginally born infants in vertex presentation have been presented in the last few years (Table II). Stewart and Reynolds (1974) reported lower mortality rate in cesarean section born infants with birth weight less than 1 500 g. Bowes et al (1979 a) demonstrated an improved survival rate in infants weighing 501-1 000 g in vertex presentation after abdominal delivery but no difference was found in infants weighing more than 1 000 g. Similar results were presented by Haesslein and Goodlin 1979, Smith et al 1980 and Fairweather 1981. Furthermore, abdominal delivery has been associated with a better survival rate in infants weighing less than 801 g or born before the 28th week of gestation (Bennett Britton et al 1981, Dillon & Egan 1981). On the other hand,

Table II. Mortality at preterm vertex delivery. Vaginal delivery vs cesarean section in relation to birth weight.

Source	Years of birth and weight or age of infants		Mortality			
			< 1000 g		1000-1500 g	
			vaginal delivery	cesarean section	vaginal delivery	cesarean section
Bowes et al (1979 a)	1975-1976 501-1500 g	NNM	14/28 (50 %)	8/21 (38 %)	10/63 (16 %)	9/37 (24 %)
Haesslein & Goodlin (1979)	Not given 800-1350 g	NNM*	14/24 (58 %)	2/9 (22 %)	14/46 (30 %)	5/25 (20 %)
Paul et al (1979)	1975-1977 1001-1500 g	NNM	-	-	14/68 (21 %)	1/20 (5 %)
Smith et al (1980)	1976-1979 750-1500 g	NNM*	25/40 (63 %)	4/20 (20 %)	24/119 (20 %)	13/69 (19 %)
Bennett Britton et al (1981)	1974-1977 < 801 g	IM	62/85 (73 %)	0/9 (0 %)	-	-
Dillon & Egan (1981)	1977-1980 24-27 weeks	M	6/10 (60 %)	14/35 (40 %)	-	-
Fairweather (1981)	1971-1977 500-1500 g	NNM	57/83 (69 %)	9/67 (13 %)	44/171 (26 %)	14/100 (14 %)

NNM = neonatal mortality (0-28 days), IM = infant mortality (18 months), M = dead before discharge from NICU

* Corrected mortality, exclusive of infants dying of major congenital anomalies, erythroblastosis fetalis etc.

conflicting results have been presented whether the mode of delivery in VLBW infants affects the long-term outcome. Some authors (Stewart et al 1974, 1977, Berg & Lindberg 1980, Bennett Britton et al 1981, Dillon & Egan 1981) report a higher intact survival rate after abdominal delivery, while others have not been able to confirm their results (Peacock & Hirata 1981, Kitchen et al 1982).

In an attempt to further investigate this question a paired matched/controlled study was designed - Paper III. Patients delivered vaginally from an infant in vertex presentation were matched against patients delivered by cesarean section. The cesarean sections were performed at indications considered not to influence the outcome, such as malpresentation or previous cesarean section. The pairs were matched with respect to gestational age, birthweight, place of delivery, place of neonatal care and date of delivery. A total of 49 000 deliveries were searched to obtain 59 well matched pairs.

The vaginally born infants had more often neonatal acidosis than cesarean section born infants - Paper III. In agreement with several other re-

ports (Hobbins et al 1972, Donald et al 1973, Papageorgiou et al 1981) there were no differences in incidence of respiratory disorders between vaginally and abdominally delivered infants. The mortality rate did not differ between the groups. At the follow-up (18-24 months) 3 infants in each group had cerebral palsy. Psychomotor retardation occurred more frequently in vaginally born (6/52) than in cesarean section born infants (0/54).

The cause of the high rate of psychomotor retardation after vaginal delivery is obscure. The groups were comparable in respect to maternal and neonatal data but hypothermia in the early postpartum period, a potential negative factor, occurred more often in vaginally born infants. The immediate postpartum care should not differ between the two groups. However, it must be taken into consideration that a preterm vaginal delivery could be a result of unanticipated emergency events preventing measures for optimal neonatal care being taken in advance. These problems are often easier to manage at a cesarean section as the exact time of delivery can be planned. Still it is not probable that the lack of "timing" in vaginal deliveries accounts solely for the difference in fetal outcome between the two groups. Other factors influencing the preterm fetus in labor, such as cerebral trauma and asphyxia ought to be considered.

The hazard of cerebral trauma at preterm labor is obvious. Preterm uterine contractions are similar in intensity to those in term labor (Kriewall & McPherson 1981, Lindgren 1981). The effect of the uterine contraction is enhanced by the rupture of the membranes, frequent in preterm labor (Lindgren 1981). When the fetal head is on the pelvic floor, the intrauterine pressure can reach 350 mm Hg during episodes of maternal bearing down efforts (Caldeyro-Barcia et al 1974). The soft skull of the preterm infant offers less resistance to compression than that of a full term infant (Kriewall & McPherson 1981). Extensive moulding of the fetal head may cause tearing of subependymal veins leading to subsequent SEH and/or IVH contributing to neonatal mortality and morbidity.

Intrapartum fetal acidosis can cause central nervous injuries with various degrees of severity causing minimal to serious handicap in the infant (Low et al 1978). The impact of asphyxia on the fetal brain is related to the stage of development (Myers 1977). In the immature infant asphyxia is connected with a high risk for intracranial hemorrhages (Pape & Wigglesworth 1979, Wigglesworth and Pape 1980). Asphyxia may cause SEH/IVH due to in-

creased cerebral blood flow (Lou et al 1979), elevated venous pressure (Lees 1980) and impairment of brain capillary endothelial (Volpe 1981). Analogous findings are reported in preterm lambs, where a combination of acidosis and an increased fluctuation in cerebrovascular transmural pressure may start bleedings into the germinal layer and ventricles (Reynolds et al 1979).

Several authors have suggested that the vaginal delivery is a significant factor in the pathogenesis of SEH/IVH (Haesslein & Goodlin 1979, Bejar et al 1980). Leviton et al (1977) found a lower incidence of SEH/IVH in infants without idiopathic respiratory distress syndrome who had been delivered by cesarean section than in infants delivered vaginally. More recently, Haesslein and Goodlin (1979) and Kosmetatos et al (1980) have demonstrated, in accordance to our results in Paper II, a lower incidence of SEH/IVH in cesarean section born preterm infants than in vaginally born. Furthermore, IVH has been diagnosed by ultrasound in the fetus during labor (Lebed 1981) and typical SEH/IVH have been described in macerated fetuses (Gröntoft 1953). Bejar et al (1980), using real time ultrasound, were able to demonstrate IVH in the first hours of life and as early as 15 minutes after vaginal delivery. There is a growing stock of data indicating that an initial damage to the brain later leading to SEH/IVH can be caused by labor and birth.

It is difficult to evaluate to what extent asphyxia in labor contributes to mortality and morbidity in preterm infants. A potential adverse effect may incorrectly be ascribed to prematurity as long as the presence or absence of acidosis is not precisely known (Beard and Rivers 1979). In Paper IV the incidence of fetal acidosis in 61 infants in preterm vaginal vertex deliveries is evaluated prospectively. Paper V provides further data in regard to neonatal and long-term morbidity in acidotic and nonacidotic infants in that material. The material comprises only singleton infants born in vertex presentation without obstetrical pathology. During labor the mothers were monitored according to a standardized program including EFM and pH assessments from fetal scalp blood at 5 cm and at full cervical dilatation. All surviving infants participated in a scheduled follow-up for at least 2 years.

A high rate of fetal acidosis was found (25 %), especially in infants born in the 28th-33rd week of gestation (see Fetal acid-base balance). Fetal heart rate changes, considered typical of fetal distress, correlated

well with fetal acidosis (see Electronic fetal monitoring). As shown by several other authors (Hobel et al 1972, Hon et al 1975, Quirk et al 1979) infants with intrapartum acidosis had a higher incidence of respiratory disorders in the neonatal period. Moreover, infants exposed to intrauterine asphyxia had more neurological abnormalities in the neonatal period and more neurodevelopmental disabilities at the long-term follow-up than non-acidotic infants of the same gestational age. Eight of the 61 studied patients had fetal acidosis at a cervical dilatation of 5 cm. Despite the fact that all these mothers were delivered within 35 minutes, 2 by cesarean section, after the diagnosis of fetal acidosis was obtained, these infants had the poorest outcome in the present study; 1 died and at the follow-up 1 infant had hemiplegia and 3 showed psychomotor abnormalities. It cannot be stated whether an earlier operative intervention would have improved the outcome for these infants. However, suggestive evidence has been presented by Bowes et al (1980) that prompt operative intervention at ominous FHR changes is of benefit for the VLBW infant. A poor long-term prognosis after prematurity and birth asphyxia in concurrence has previously been reported by several other authors (Davies & Stewart 1975, Robertson & Tizard 1975, Mac Donald et al 1980, Mulligan et al 1980). However, the diagnosis of intrapartum acidosis has not been confirmed by fetal scalp pH assessments in any of these studies.

The present results suggest that infants born in vertex presentation in the 34th-36th week of gestation, which approximately accounts for 80 % of all preterm vertex deliveries do well at vaginal delivery. It seems therefore reasonable to manage these deliveries according to the same principles applied to term labor. In contrast, vaginal delivery of infants in vertex presentation in the 28th-33rd week is associated with a considerable risk for intrapartum acidosis. Since intrapartum acidosis has a potential adverse impact on short-term and long-term outcome it is important that these patients are carefully monitored during labor. At ominous FHR patterns a low threshold for prompt cesarean section delivery is recommended.

Infants born before the 30th week of gestation or with an estimated birth weight of less than 1 000 g constitute a special obstetric problem. Internal fetal monitoring is often required to obtain a FHR-tracing of good quality in these weeks of gestation (see Electronic fetal monitoring). Amniotomy must then be considered in spite of the increased potential risk of the procedures for cerebral trauma and umbilical cord compression (Caldeyro-Barcia et al 1974). Moreover, the progress of labor is often

difficult to evaluate and precipitous labor is common, which is less well tolerated by preterm fetuses (Bishop et al 1965). Because of these circumstances several obstetricians (Fanaroff & Merkatz 1977, Hobel & Oakes 1980, Bowes 1981) have proposed that primary cesarean section could be an appropriate strategy for very preterm infants. Several authors (see Table II) have presented suggestive evidence that cesarean section in these infants do have advantages. However, it is too early to state that these possible advantages, attributed to cesarean section, depend on the avoidance of labor and vaginal delivery, or are a result of a better "timing" of the abdominal delivery, or just reflect an optimistic approach of the obstetrician and neonatologist involved. Until a prospective, well controlled study is available this question remains unsettled.

The improved outcome in infants born before the 30th week of gestation has raised the following question: at what gestational age shall the obstetrician be prepared to intervene on fetal indications? This decision is strongly influenced by the perinatal outcome in the hospital in which the delivery is to take place. It is therefore difficult to present precise recommendations. Most obstetricians agree that these mothers should be delivered in centres where optimal facilities are available immediately after birth. Therefore pre-delivery maternal-fetal transports are used increasingly (Merenstein et al 1977, Lamont et al 1983). Today, considering the development of pulmonary alveoli type II cells, the 24th week is the lowest gestational age at which one can expect extrauterine life (Maxwell 1980). Several centres have reported 50 % survival rates and a rather low incidence of neurological sequelae after the 26th week of gestation (Stewart et al 1977, Shennan & Milligan 1980, Driscoll et al 1982). Leading perinatal centres advise a supporting attitude to the fetus from the 26th week of gestation (Bowes et al 1979, Paul et al 1979, Milligan & Shennan 1980, Fairweather 1981). Caution is necessary in the application of these recommendations since their results represent highly specialized centres. The effects of cesarean section on the maternal morbidity and of the anesthetic drug exposure on the immature infant remain also to be elucidated. In the individual case the obstetrician must decide on the safest method of delivery by taking into consideration all the circumstances of the case - keeping in mind results and facilities available.

Antepartum

Antenatal cardiotocography (CTG) is an important tool in modern obstetric care. The obstetric literature is abounding with reports of the validity and usefulness of this procedure (Solum 1980). However, experience of CTG has been gained mostly in term pregnancies and our knowledge about the method, when used in preterm pregnancies, is rather limited. In recent years there is a growing interest for the developmental aspects of the CTG, and it has been shown that several variables of the FHR shift with advancing gestational age. In interpreting the FHR of the preterm fetus it is therefore important to take the continuous maturation of the fetus into consideration.

The FHR of the human fetus increases until the 9th week of gestation (166-176 beats/min) (Robinson & Shaw-Dunn 1973) and decreases thereafter progressively until the 30th week of gestation (110-150 beats/min) (Ibarra-Polo et al 1972, Wheeler & Murrills 1978). From then on and until term only a reduction of the basal line can be observed. Suggestive evidence has been presented by Schifferlie and Caldeyro-Barcia (1973) that the decrease in FHR with advancing development does reflect a gradually increasing vagal tone.

The baseline variability consists of two components; short-term variability, defined as the change occurring in successive R-R interval-to-interval differences, and long-term variability defined as the changes occurring in successive R-R interval lengths. Short-term variability is considered to be caused by moment-by-moment changes in parasympathetic activity, and long-term variability by opposing activities of the sympathetic and parasympathetic systems (de Haan et al 1979). Concomitantly, with the decrease in FHR both the short-term and long-term variability increase with maturation (Wheeler et al 1979). Analogous findings are reported in works on immature neonates (Cabal et al 1980).

Even the pattern of accelerations differs with different gestational ages. The number of accelerations is progressively rising toward term, with the greatest increase between 28th-34th week (Dawes et al 1982). Accelerations are prevailing over decelerations after the 30th week of gestation (Visser et al 1981). The frequency of decelerations seems to be unchanged during gestation, but qualitative changes do occur. Before the

30th week of gestation decelerations appear mostly as a solitary brief deceleration, whereas later in gestation decelerations, associated with accelerations, show an increasing frequency (Dawes et al 1981, 1982).

The relationship between FHR and fetal movements (FM) forms the basis for the nonstress test (NST). A "normal" NST should demonstrate FHR accelerations associated with FM in a stipulated span (Solum 1980). In Paper VI the relationship between FHR and FM is investigated in relation to gestational age. Four healthy women were followed weekly from the 25th week of gestation until term with abdominal ECG recordings of 40 min duration under standardized conditions. Maternal perception of FM was registered and all data regarding FHR and FM were computer analyzed.

The results in Paper VI indicate that the relationship between FHR and FM is altered with increasing maturity. After the 30th week of gestation accelerations were concomitantly recorded in almost 90 % of the FM periods. Before that age, i.e. 25th-30th week, accelerations occurred in only 21 % of the FM periods. Decelerations were associated with FM in weeks 25-30 while in later gestation no such association could be observed. These results are in agreement with other recently published reports (Aladjem et al 1981, Dawes et al 1982, Sorokin et al 1982). Paper VI also confirms the report by Wheeler et al (1979) that the long- and short-term variability increases in relation to advancing gestational age.

The absence of accelerations combined with a decreased variability in a normal fetus in the 25th-30th week of gestation can result in a classical non-reactive pattern. Furthermore, the occurrence of decelerations at FM may be falsely interpreted as a pathological NST. However, it must be emphasized that these FM-related decelerations are variable decelerations of short duration (15-30 sec) and with a moderate beat loss (< 30 beats). They differ considerably in appearance from the decelerations usually referred to as fetal distress.

Bishop (1981) found no difference in the incidence of non-reactive NSTs in a high versus low risk population before the 30th week of gestation. In a recently published study of NST and contraction stress test (CST) of 428 high-risk gravidas in the 25th-34th week of gestation Devøe (1982) had no fetal loss in patients with a non-reactive NST combined with a negative CST. Thus, the non-reactivity in very preterm pregnancies seems to be a function of gestational age rather than an indicator of fetal distress.

Can the CST serve as a reliable guide at non-reactive NSTs in preterm

pregnancies? Gabbe et al (1978) and Devoe (1982) have studied the predictive value of CST to fetal mortality and morbidity in preterm pregnancies. They reported false-positive and false-negative rates for CSTs before the 34th week similar to those figures reported for term pregnancies. However, their series include a relatively limited number of CSTs performed before the 30th week of gestation, and the implication of the method in these weeks needs to be further investigated.

In conclusion, the FHR base line decreases progressively with advancing gestational age and is accompanied by an increase in long-and short-term variability and an increase in the frequency of accelerations. Furthermore, the relationship between FHR and FM is altered by maturity. These qualitative and quantitative changes in FHR predominantly occur before the 30th week of gestation. This should be kept in mind when using antepartum CTG in the surveillance of preterm pregnancies.

Intrapartum

Intrapartum asphyxia occurs more often in preterm labor than in term labor (Cibils 1975, Low et al 1975, 1981). For diagnosis and prevention of asphyxia, EFM is strongly recommended. Preterm infants, monitored during labor, have a more favorable outcome than those of comparable weight and gestational age who are not monitored (Paul et al 1980).

Hitherto most studies of EFM in preterm deliveries have analyzed its predictive value to neonatal outcome (Hobel et al 1972, Martin et al 1974, Bowes et al 1980). So far, few studies have correlated FHR-changes during preterm labor with fetal scalp pH. Hobel et al (1972) in a study of 25 low birth weight infants reported that those with abnormal FHR patterns had significant metabolic and respiratory acidosis during the intrapartum and the immediate postpartum period. More recently, Zanini et al (1980), in a retrospective study of 62 preterm infants, demonstrated a close association between abnormal FHR-patterns and fetal acidosis.

Owing to the limited information on this subject, a prospective study on the relationship between FHR patterns and fetal acid-base balance has been carried out (Paper IV). Sixty-one patients were followed according to a standardized program. All FHR recordings were performed by internal technique since external methods are difficult to utilize in preterm labor, i.e. especially when monitoring by abdominal ECG in the 27th-34th week of gestation where the amplitude of the fetal ECG is low (Wheeler et al 1978,

Kariniemi et al 1982). In these preterm vertex deliveries abnormal FHR patterns were often recorded, especially before the 34th week of gestation. The most common FHR changes were tachycardia, decreased variability and variable decelerations, which were recorded in 43 %, 39 %, 61 %, respectively in all studied patients. The high frequency of tachycardia and decreased variability may reflect the degree of immaturity in the studied population. These FHR changes were actually recorded in an increasing frequency with lowering gestational age. In patients, not treated with β -agonists, these FHR-changes show a positive correlation to fetal acidosis, stressing the value of these patterns as predictors of fetal asphyxia even in preterm labor. In the present study tachycardia was defined as a heart frequency over 160 beats/minute. This seems to be an adequate limit in preterm deliveries, whereas in term labor suggestive evidence has been presented that the normal upper limit of the base line should be 150 beats/minute (Caldeyro-Barcia et al 1970, Beard et al 1971).

The incidence of variable decelerations (61 %) is considerably larger than the 20-30 % rate reported in normal term labor (Westgren et al 1980). Zanini et al (1980) reported a similar high frequency and suggested that the relatively decreased amount of amniotic fluid and the decreased protective effect, caused by less Wharton's jelly in the cord of the preterm infant, predispose to umbilical cord compression causing variable decelerations. Furthermore, variable decelerations are associated with ruptured membranes (Cibils 1978); this could partly explain the high incidence of variable decelerations in the present study since all patients had ruptured membranes. In immature neonates, variable-like decelerations can be observed at various types of sensoric and motoric stimulus (Kattwinkel et al 1976, Maurer 1979). It is reasonable to assume that this tendency to bradyarrhythmia is valid even in the intrapartum period. Thus, variable decelerations might also be a sign of immaturity of the fetal cardioregulatory mechanisms.

In accordance to previous reports (Hobel et al 1972, Paul 1977, Bowes et al 1980, Zanini et al 1980) a close association could be demonstrated between FHR-changes, considered typical for fetal distress (i.e. silent pattern and late or pronounced variable decelerations), and fetal acidosis. The results suggest furthermore that moderate variable decelerations (< 60 beat loss) are less well tolerated by the very immature than by more mature fetuses since several of the most immature acidotic fetuses had moderate variable decelerations of innocent appearance. Some of these

patients had a V-shaped deceleration with an overshoot pattern, a finding associated with depressed immature neonates (Goodlin & Lowe 1974). The clinical significance of these "innocent" variable decelerations in very preterm deliveries remains to be investigated as this type of deceleration in the present study was recorded mostly in patients with asphyxia of short duration during the second stage of labor, and these infants did well after birth.

The fetal outcome, in relation to intrapartum FHR-pattern, is presented in Paper V. All surviving infants participated in a 2-year follow-up study. Infants who had intrapartum ominous FHR patterns (repetitive pattern of late or pronounced variable decelerations) showed a positive correlation to neurological abnormalities in the neonatal period and to neurological disabilities in the follow-up study. Bowes et al (1980) were unable to demonstrate that ominous FHR changes in infants with birth weight of 1 500 g or less predicted neurological abnormalities in the neonatal period. The discrepancy between their results and ours is probably related to differences in intrapartum management of these deliveries (see Preterm vertex delivery). In their study the incidence of long-term sequelae was unfortunately not evaluated. In term fetuses, however, Painter et al (1978) showed that infants with normal FHR-patterns had a favorable development in the first years of life compared to infants who had ominous FHR-patterns in the intrapartum period. These results are in agreement with our findings. Thus, conditions associated with ominous FHR patterns appear to affect adversely the outcome in both preterm and term deliveries.

In conclusion, EFM constitutes an important factor in the intrapartum management of preterm deliveries. Tachycardia, decreased variability, late and pronounced decelerations are associated with fetal acidosis. Furthermore, the tolerance of moderate variable deceleration decreases in less mature fetuses. Owing to the potential adverse impact on fetal outcome prompt recognition and therapy are required at ominous FHR-patterns in preterm labor.

FETAL ACID-BASE BALANCE

According to EFM studies fetal asphyxia is common in preterm labor (Cibils 1976). A more accurate diagnosis of intrapartum asphyxia can be achieved by fetal scalp blood pH assessments and by measuring the acid-base status in umbilical cord artery (Jacobson 1970). Until today only few

studies present data on fetal acid-base status in preterm deliveries.

In a study of 64 patients in preterm labor Low et al (1975) reported a 31 % incidence of metabolic acidosis (buffer base less than 36.1 mEq/litre in umbilical artery); the incidence being higher when prematurity was associated with additional complications. For patients in preterm labor without additional complications the incidence was 14 %, i.e. a six-fold increase compared to normal deliveries in their population. More recently the group of Low (1981) has shown that the incidence of metabolic acidosis increases with decreasing maturity. This was most pronounced in small for date infants, but was also apparent in appropriate for gestational age infants; e.g. of 39 infants with birthweight above the 25th percentile delivered before the 31st week 11 (28 %) had metabolic acidosis. Moreover, in a retrospective study of 62 low birth weight infants Paul (1977) reported a 35 % incidence of fetal acidosis (scalp pH < 7.25).

Papers IV-V provide further data in respect to fetal acid-base balance in preterm vertex deliveries. Only patients in preterm labor without additional maternal or fetal complications were studied. All 61 patients were followed with fetal scalp pH assessments at a cervical dilatation of 5 cm and at full cervical dilatation. At 5 cm dilatation 8 patients had fetal acidosis (scalp blood pH < 7.25). At full cervical dilatation 12 patients had fetal acidosis. In total 15 of 61 patients (25 %) had intrapartum fetal acidosis. In accordance with the findings of Low et al (1981) fetal acidosis occurred more often in the very preterm delivered infants than in the more mature ones. Furthermore, 7 of 12 patients with fetal acidosis at full cervical dilatation had normal pH 40 min earlier, suggesting that fetal pH in immature infants can change rapidly during the second stage of labor. These findings are in accordance with postnatal observations of preterm infants (Yu et al 1965) where even short hypoxic periods are followed within minutes by a falling pH. Infants with intrapartum acidosis had a significantly lower pH at birth and regained in the postpartum period a normal pH more slowly than non-acidotic infants.

In conclusion, the presented data indicate that the preterm infant in vertex presentation runs a considerable risk to develop fetal acidosis during labor. Fetal acidosis was diagnosed predominantly in deliveries before the 34th week of gestation. Fetal scalp blood pH assessments are of great value in the surveillance of the patient in preterm labor.

GENERAL SUMMARY AND CONCLUSIONS

The present work studied EFM of preterm pregnancies in the antepartum and intrapartum period and the significance of the mode of delivery in preterm deliveries.

The FHR was investigated by a longitudinal study in normal pregnancies from the 25th week of gestation until term. The FHR base line decreased progressively with advancing gestational age and was accompanied by an increase in long- and short-term variability. The relationship between FHR and FM was altered with increasing maturity. After the 30th week of gestation accelerations were concomitantly recorded at FM. Before that age accelerations occurred rarely, and decelerations of FHR were predominant at FM. The results emphasize the importance of considering the cardiotocogram of an immature fetus as a function of gestational age rather than as a definite indicator of the fetal status.

Electronic fetal monitoring and fetal acid-base status were prospectively studied in preterm vertex deliveries. Tachycardia, decreased variability and variable decelerations were common, and these FHR changes were recorded in an increased frequency at lower gestational age. Ominous FHR patterns, considered typical for fetal distress, were very frequently associated with fetal acidosis and were related to a low fetal scalp pH similar to that reported in studies of mature fetuses. Furthermore, the results suggest a maturity related correlation between variable decelerations and fetal acid-base status, since moderate variable decelerations were less well tolerated by the very immature than by more mature fetuses.

In preterm vertex deliveries mild intrapartum fetal acidosis was common in patients without additional complications but occurred predominantly before the 34th week. In infants with intrapartum fetal acidosis, especially those with early intrapartum acidosis, the rate of neonatal neurological abnormalities and neurodevelopmental disabilities at the 2 years follow-up was higher than in non-acidotic infants of the same gestational age. Moreover, in the analyses of the mode of delivery in preterm infants less than 1 500 g and 2 000 g respectively (Paper II, III) vaginal vertex delivery, compared to cesarean section, was associated with an increased incidence of intracranial hemorrhages and neurodevelopmental abnormalities in later infancy. Thus, these data suggest that labor and vaginal delivery at preterm vertex presentation are associated with a potential adverse impact on fetal short-term and long-term outcome.

Since fetal acidosis occurred mainly before the 34th week different obstetric managements of preterm vertex deliveries might be applied before and after this week of gestation. In the 34th-36th week of gestation intrapartum fetal distress seldom occurred and the infants did well after vaginal delivery. Consequently these deliveries ought to be managed according to principles similar to those applied to term deliveries. In contrast, vaginal vertex delivery before the 34th week is associated with a considerable risk for intrapartum acidosis. A more careful intrapartum surveillance is desirable in these patients and adequate recognition and prompt intervention are required at signs of fetal distress.

At preterm breech delivery before the 33rd week of gestation, patients delivered by cesarean section had a lower mortality rate than those delivered vaginally, but from the 33rd to the 36th week of gestation there was no difference in mortality. However, at the long-term follow-up abdominal delivery was associated with an improved infant outcome in respect to neurological sequelae. Therefore, a routine use of cesarean section at preterm breech presentation seems to be indicated not only before the 33rd week of gestation but must also be considered in the 33rd-36th week of gestation.

The present study is the result of a close cooperation between obstetricians and neonatologists. In the future, such a perinatal approach to problems concerning patients in preterm labor and delivery is essential to ensure continuing improvements in perinatal care.

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LONG-TERM FOLLOW-UP OF PRETERM INFANTS IN BREECH PRESENTATION DELIVERED BY CÆSAREAN SECTION

A Prospective Study

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Summary All forty-two breech infants delivered by caesarean section before the 37th gestational week since Jan. 1, 1975, were followed up prospectively. Outcome in this group was compared with that for all forty-eight preterm breech infants delivered vaginally in 1971-74, before the introduction of routine caesarean section. Delivery by caesarean section significantly reduced the frequency of severe prolonged asphyxia, and neonatal mortality was reduced from 14.6% to 4.8%. At 12 months of age 24% of those delivered vaginally had developmental or neurological abnormalities compared with 2.5% of those delivered by caesarean section.

Introduction

WITH breech presentation the risk of cord complications, incoordinate labour, intrapartum hypoxia, aspiration pneumonia, and traumatic injuries is considerable.¹⁻³ Increased fetal mortality and morbidity in premature infants are partly due to neonatal risks and partly to the risk of skull trauma and asphyxia during delivery. The survival of very premature infants can now be achieved with intensive care.⁴

It has been claimed that many intrapartum risks—e.g., intrauterine asphyxia, cord and placental accidents, and traumatic injuries—can be avoided by caesarean section.^{2,3,5,6} Cruikshank and Pitkin⁷ suggested that fetal outcome after routine caesarean section should be prospectively compared with outcome after vaginal breech delivery.

Retrospective analysis has shown a poor outcome in preterm breech infants delivered vaginally.⁸ We have evaluated the long-term outcome of routinely performing caesarean section in all such deliveries before the onset of the 37th gestational week.

Materials and Methods

All singleton pregnancies with infants in breech presentation admitted to the Department of Obstetrics and Gynaecology, University Hospital, Lund, from Jan. 1, 1971 to Feb. 1, 1977, and delivered before the 37th week of gestation were studied. The obstetric management of the two groups (group A, forty-eight preterm infants [1971-74]; group B, forty-two preterm infants [1975 to March 1, 1977]) was different. The prospective study began on Jan. 1, 1975, with routine caesarean section as method for delivery of group-B infants. For comparison, the records of infants in group A (all vaginally delivered) were evaluated retrospectively. Besides the ninety liveborn infants in this study, seven mothers (six 1971-1974 and one 1975-1977) were admitted to the hospital with dead infants in breech presentation. These infants were excluded from the investigation.

Obstetric Management

Premature delivery is defined as delivery before the 37th week of gestation. Gestational age was calculated from the date of the last menstrual period and by means of repeated clinical and ultrasonic examinations. Provided that delivery had not advanced too far—i.e., cervix was not more than 4 cm dilated—a β_2 -receptor stimulator, terbutaline, was given to inhibit premature labour.⁹

Since 1973, corticosteroid prophylactic treatment has been given to most mothers with intact membranes and impending preterm delivery.¹⁰ Electronic heart-rate monitoring was routinely performed.

Neonatal Management

1 and 10 min Apgar scores were determined in every baby. The birth data were plotted on Swedish standard curves relating birth-weight and birth-length, on the one hand, and birth-weight and gestational age, on the other. All infants with birth-weight below 2500 g and larger babies with asphyxia or other neonatal complications were transferred to the neonatal intensive care unit (N.I.C.U.). If hyaline membrane disease (H.M.D.) was diagnosed, continuous positive airways pressure (C.P.A.P.) treatment by a face chamber (Fc-100, Siemens-Elma) technique was started.¹¹ Infants with recurrent apnoea and bradycardia were intubated and treated with intermittent positive-pressure ventilation (I.P.P.V.).¹² Necropsy was performed on all infants who died.

Follow-up Study

At discharge from the N.I.C.U., the following examinations were performed: neurological with skull transillumination; lumbar puncture with cytology of the cerebrospinal fluid;¹³ and ophthalmology. The infants were re-examined at age 5-6, 9-11, and 14-18 months and 2-4 years. These examinations

included developmental and neurological examination, and at 9–18 months, an audiometry test and also an ophthalmological re-examination. Parental and institutional consent for the neonatal and follow-up examinations had been obtained.

Statistical Methods

The χ^2 test was used for group comparisons. P values above 0.05 were not regarded as being significant.

TABLE I—NEONATAL DATA AND EVENTS

Data	Group A	Group B	P value
Total number	48	42	..
Boys/girls	27/21	18/24	..
Birth-weight (g):			
Mean (1 s.d.)	2024±615	2020 (647)	
Range	760–2850	1020–3250	N.S.
Gestational age (wk):			
Mean (1 s.d.)	33.4 (2.7)	33.7 (2.4)	N.S.
Range	28–36	28–36	
S.G.A. (less than -2 s.d.)	5	4	N.S.
PROM (more than 24 h)	7	9	N.S.
Asphyxia:			
Short (Apgar score <7 at 1 min)	10	14	N.S.
Prolonged (Apgar score <7 at 10 min)	18	4	<0.01
Respiration difficulties:			
Hyaline-membrane disease	4	5	N.S.
Transient tachypnoea	4	8	N.S.
Respiratory insufficiency	3	3	N.S.
Assisted ventilation	7	9	N.S.
Days of treatment in N.I.C.U. (mean)	34	38	N.S.
Survivors:			
Neonatal mortality (0–28 days)	41	40	..
Total outcome (neonatal mortality + long-term sequelae)	7 (14.6%)	2 (4.8%)	N.S.
	17 (35.4%)	3 (7.1%)	<0.01

S.G.A.=small for gestational age.

PROM=premature rupture of the fetal membranes.

Results

All forty-eight group-A children were delivered vaginally. Caesarean section was performed in thirty-nine out of forty-two of group-B patients (93%); the other three could not be delivered by this method because labour was too far advanced at admission.

Apart from a significantly higher incidence of severe prolonged asphyxia in vaginally delivered children (37.5% in group A and 9.5% in group B) there was no difference in the frequency of various neonatal events (table 1). The duration of treatment in the N.I.C.U. was similar in groups A and B, averaging 34 and 38 days, respectively.

Neonatal Outcome

Seven of the forty-eight group-A infants (14.6%) and two of the forty-two group-B infants (4.8%) died (table 1). Table 11 gives data on the nine who died. All except two died within 12 h of birth. One in each group died from lethal congenital malformations of the kidney or from severe rhesus immunisation with hydrops fetalis—i.e., both infants in group B died from causes unrelated to the method of delivery. Intracranial haemorrhage was found at necropsy in six of seven group-A infants and one group-B infant. Two infants in group A had tentorial rupture. All infants who died had experienced prolonged postnatal asphyxia and had had a low Apgar score.

Eleven of forty-one group-A infants (27%) but only two of forty group-B infants (5%) had transient neurological abnormalities during the neonatal period—i.e., obvious feeding difficulties and abnormal hypotonia in eleven group-A infants and two group-B infants. Jitteriness or convulsions occurred in five group-A infants.

TABLE II—NECROPSY FINDINGS IN INFANTS DYING IN NEONATAL PERIOD

Case no.	Sex	Birth-weight (g)	Gestational age (wk)	Apgar score 1 min/10 min	Age (h)	Necropsy findings
<i>Group A:</i>						
A1	F	1010	28	1/5	11	Tentorial rupture, I.C.H. (intracerebellar)
A2	M	1200	32	2/6	6	I.C.H. (terminal vein)
A3	M	1850	30	3/5	70	Hydrops fetalis (Rh immunisation), tentorial rupture, I.C.H. (intracerebellar)
A4	F	2000	34	3/4	1	H.M.D.
A5	M	1390	32	2/1	1	I.C.H. (terminal vein), renal agenesis
A6	M	1175	28	4/5	10	I.C.H. (terminal vein), H.M.D.
A7	M	1320	28	2/3	3	I.C.H. (terminal vein and intracerebellar)
<i>Group B:</i>						
B1	M	1800	34	2/4	24	Multicystic kidneys (anuria), coarctation of aorta
B2	M	1500	32	1/5	11	Hydrops fetalis (Rh immunisation), I.C.H. (intracerebellar)

I.C.H.=intracranial haemorrhage.

H.M.D.=hyaline membrane disease.

The rate of cerebrospinal fluid (c.s.f.) hæmorrhage¹³ was studied in thirty-three of forty-one group-A infants and thirty-two of forty group-B infants. In the other infants, c.s.f. examination could not be performed because of parental refusal or unsuccessful lumbar puncture. The incidence of c.s.f. bleeding was significantly higher in group A (13 of 33 infants, 39%) than in group B (3 of 32 infants, 9%).

Long-term Outcome

To date, follow-up examinations have been performed in all surviving infants at 1–5 years of age. Ten of forty-one group A (24%) but only one of forty group B (2.5%) have developmental or neurological abnormalities (table III). Neonatal cytological c.s.f. examination was abnormal in all except two of these eleven infants. Two group-A infants had subdural hæmatoma requiring neurosurgical evacuation at 4 and 6 months of age. In one infant (case A 13) vaginal breech delivery probably caused the spinal-cord injury which resulted in initial flaccid paralysis, and later produced hypertonus and tetraplegia.

The accompanying figure shows the distribution by birth-weight of infants with long-term sequelæ. Neonatal mortality and long-term abnormalities were significantly more common in group-A infants (17 of 48 [35%]) than in group-B infants (3 of 42 [7.1%]) ($P < 0.01$) (table I). Long-term sequelæ (table III and figure) occurred in all birth-weight and gestational-age groups. However, because numbers in the different weight groups were small a detailed analysis of frequency of complications within each of these groups was not possible.

Discussion

The design of this study is open to criticism because results from different periods are compared. During this time, obstetric and neonatal care has improved. For example, treatment with corticosteroids for induction of lung maturity was started in 1973. However, the incidence of hyaline membrane disease and other respiratory difficulties is similar in groups A and B (table I). Data on birth-weight, gestational age, incidence of small-for-gestational-age infants, premature rupture of the fetal membranes, and fetal monitoring were also similar in the two groups. The introduction of I.P.P.V. and parenteral nutrition in very-low-birth-weight infants in

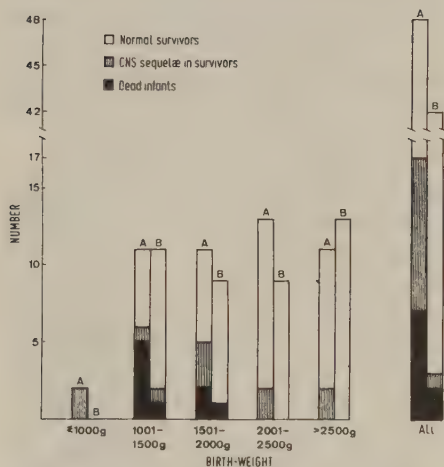
TABLE III—DEVELOPMENTAL AND NEUROLOGICAL SEQUELÆ IN SURVIVING INFANTS

Case no.	Sex	Birth-weight (g)	Gestational age (wk)	Apgar score 1 min/10 min	C.S.F.*	Developmental and neurological sequelæ
<i>Group A:</i>						
A 8	M	1300	30	1/6	0	C.P. ataxia, retrolentatal fibroplasia
A 9	M	1860	36 (S.G.A.)	10/10	0	Moderate psychomotor retardation, clumsy child
A10	M	2630	36	8/10	+	Subdural hygroma, moderate psychomotor retardation
A11	F	2140	36	3/10	+	Moderate psychomotor retardation strabismus
A12	F	1780	32	8/9	+	Subdural hygroma, transient dystonia
A13	M	2970	36	1/8	+	C.P. tetraplegia, severe psychomotor retardation, astigmatism
A14	F	760	29 (S.G.A.)	1/3	+	C.P. diplegia
A15	M	820	30 (S.G.A.)	4/8	+	C.P. diplegia
A16	M	1680	30	2/6	+	C.P. diplegia, moderate psychomotor retardation
A17	M	2170	36	2/5	+	C.P. ataxia, transient dystonia, moderate hearing loss
<i>Group B:</i>						
B 3	F	1400	34 (S.G.A.)	3/9	+	Moderate psychomotor retardation, clumsy child

C.P.=cerebral palsy.

S.G.A.=small for gestational age.

* Cytological examination (0=normal findings, +=siderophagocytes indicating bleeding)



Distribution of neonatal mortality and long-term C.N.S. sequelae in different birth-weight groups of groups A and B.

1970-71¹² and C.P.A.P. treatment of hyaline membrane disease in 1972¹¹ were major changes in routine care in our N.I.C.U. The introduction of these improvements in neonatal management at the beginning of the study period could hardly have had any appreciably different effects on the outcome in the two study groups.

Randomised assignment to caesarean section or vaginal delivery would have been difficult. Apart from the ethical aspects of such random allocation, it is difficult to avoid selection. Data from 71 European departments show that only a minority of obstetricians are prepared to perform a caesarean section for fetal reasons before the 30th gestational week; about 50% are prepared to do so at about the 33rd week.⁵ If the infants in the lowest weight group, in whom neonatal mortality is likely to be increased (see accompanying figure), were delivered by caesarean section for only maternal and not for fetal reasons, evaluation of such a study would be difficult.

Fetal monitoring is also difficult in these cases.¹⁴ Accurate recordings can be difficult to obtain, since only external methods are available for much of delivery, and there are practical problems in getting fetal blood-samples for pH determination. Besides these factors, interpretation of the recordings gives rise to special problems. The degree of asphyxia can therefore be difficult to estimate.⁵ In a randomised study of routine caesarean section vs vaginal delivery (with caesarean section only for specific indications), these unpredictable factors could prevent a comparison of the two groups.

Cruikshank and Pitkin⁷ stressed the possibility of improving neonatal outcome after vaginal delivery by intensive electronic heart monitoring, epidural anaesthesia, and forceps delivery of the aftercoming head. However, published reports do not support this view. Milner¹⁵ demonstrated that the use of forceps on the aftercoming head reduced the mortality-rate, but still found it as high as 22% in weight groups 1000-1499 g and 11% in 1500-1999 g. Crawford¹⁶ claimed that vaginal delivery with epidural anaesthesia is as good as, if not better than, caesarean section. He investigated forty-four premature breech infants: twenty-four were delivered vaginally without and eight with epidural block and twelve by caesarean section. Only one patient in the epidural group had "obstetric pathology" compared with six of twelve in the caesarean-section group. These heterogeneous groups were hardly comparable and the incidence of long-term sequelae was not investigated.

In the present investigation, the total neonatal mortality (0 to 28 days after birth) was reduced from 14.6 to 4.8% (N.S.). Exclusion of infants with lethal malformations increases the difference in neonatal mortality between the two groups (table II). There were fewer early deaths in preterm breech infants delivered by caesarean section. Moreover, C.S.F. haemorrhages were less common in infants delivered by caesarean section (9%) than in vaginally delivered infants (39%). There were C.S.F. cytological signs of bleeding in 10% of infants after normal deliveries without asphyxia.¹³ It is not certain this C.S.F. bleeding was caused by traumatic intracranial or spinal haemorrhage or by asphyxia. However, the occurrence of tentorial rupture, subdural haematoma, and spinal-cord injury in five infants in group A could indicate that the risk of birth trauma is greater after vaginal delivery than after caesarean section.

The effect of changes in routine perinatal care is best assessed by long-term follow-up. At follow-up at 1-5 years of age 24% of the vaginally delivered infants and

2.5% of those delivered by caesarean section had developmental or neurological sequelæ ($p < 0.01$). In all children, signs of long-term sequelæ appeared within the first year. Therefore the incidence of such sequelæ is unlikely to change in controls after they reach the age of 1 year. Whether our active approach to treatment during the perinatal period will affect the occurrence of so-called minimum brain damage will require further follow-up studies in school-age children.

Routine caesarean section performed because of impending preterm breech delivery improved neonatal mortality and morbidity and also reduced long-term neurological sequelæ. This approach seems to be justified even in very early delivery (gestational age 27–30 wks) provided that adequate obstetric and neonatal intensive care is available.

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DELIVERY AND LONG-TERM OUTCOME OF VERY LOW BIRTH WEIGHT INFANTS

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Abstract. The obstetric and the neonatal management of 72 infants weighing less than 1 500 g at birth were evaluated. Sixty per cent of the mothers were delivered by cesarean section. The neonatal mortality (27%) was equal in the cesarean section and the vaginally delivered groups, but intra-ventricular hemorrhage was a more frequent autopsy finding in the latter group.

At follow-up, 88% of all surviving infants are neurologically normal at two years of age. Of the vaginally delivered infants, three suffered from cerebral palsy, but none in the cesarean section group. The present results reveal that an active management including cesarean section in the delivery of very low birth weight infants is justified and leads to a favorable prognosis.

The neonatal care of preterm infants has considerably improved during recent years. The neonatologists today report encouraging low mortality and morbidity rates even for infants with very low birth weight (VLBW): 1 500 g or less (5).

The condition at birth of these infants is of major importance for the prognosis; the obstetrician's problem is therefore how best to deliver these infants. Recently, it has been claimed that cesarean section is preferable in very preterm deliveries, especially in pregnancies with additional obstetric complications (6, 19).

At the University Hospital of Lund, Sweden, a fixed policy for impending preterm deliveries with an estimated fetal birth weight less than 1 500 g has been implemented since 1975. This paper treats the obstetric and neonatal care of these infants. All surviving VLBW infants have been followed for at least two years.

PATIENTS AND METHOD

The investigation includes all singleton infants weighing less than 1 500 g (VLBW) born 1975–1978 at the Department of Obstetrics and Gynecology, University Hospital, Lund, Sweden. During the period involved 12 773 singleton infants were born. Seventy-two of these infants (5.6 per mille) weighed less than 1 500 g. Antenatal deaths are excluded.

Obstetric management. All mothers had undergone repeated clinical examinations during pregnancy. At admission to the labor ward, a close physical examination was made. Gestational age was estimated from date of the last menstrual period, and where dates were unreliable, biparietal diameter was measured by ultrasound.

At impending preterm delivery, a β -receptor stimulator, terbutaline, was given to most mothers (8). Premature rupture of the membranes was conservatively treated by bed rest and supply of terbutaline and sedatives (3). Antibiotics were only given on signs of intrauterine infections. Ampicillin was then administered parenterally and the patients were delivered promptly.

Prophylactic treatment with corticosteroids was given to most mothers with intact membranes in impending preterm delivery. The lecithin/sphingomyelin ratio in amniotic fluid was measured in selected cases. During vaginal delivery, electronic fetal heart rate monitoring was routinely performed, and pH measurements were made in selected cases (7). Episiotomy was performed routinely.

Cesarean section was performed if the fetus showed signs of growth retardation or was in other presentation than vertex. In addition, maternal complications such as pre-eclamptic toxemia, diabetes mellitus, Rhesus immunization, and vaginal hemorrhage (abruptio placentae and placenta praevia) led to abdominal delivery. All cesarean sections were performed by a transverse incision in the lower uterine segment. To facilitate the extraction of the infant at cesarean section, terbutaline was given as a bolus injection (250 μ g i.v.) to most mothers before opening the uterine cavity. After clamping the cord, a non-selective blocker, propranolol (1 mg i.v.) was given in some cases to control the bleeding from the relaxed uterine muscle (2).

Neonatal management. After delivery, initial stabilizing procedures were performed in the resuscitation room in the delivery ward, i.e. control of ventilation, oxygenation, and thermoregulation. The baby was shown to the parents before transfer in transport incubator to the neonatal intensive care unit (NICU).

All babies were nursed in incubators. On admission to the NICU, umbilical artery and venous catheters were inserted. The babies were constantly supervised by a nurse during the intensive care period. Respiration, heart rate, and temperature were continuously monitored. Acid-base balance was measured repeatedly during the first days, and metabolic acidosis was corrected.

Infants developing ventilatory insufficiency, either because of idiopathic respiratory distress syndrome (IRDS) or recurrent apnea of immaturity (AR) in spite of 60% inspired oxygen, were started on continuous positive airways

Table 1. *Obstetric data and events. Vaginal delivery n = 29, cesarean section n = 43.*

	Vaginal delivery	Cesarean section	
		Elective	Acute
Total number	29	24	19
Presentation			
Vertex	29	18	4
Breech	—	6	14
Transverse lie	—	—	1
Complications			
Preeclamptic toxemia	—	10	—
IUGR	3	10	1
Diabetes mellitus	—	2	—
Rhesus immunization	—	2	—
Vaginal hemorrhage	5	—	6
I.U. infections	2	—	1
Corticosteroid prophylaxis	10	6	9
Onset of delivery			
Preterm labor	18	—	9
PROM > 24 h	6	—	4
Hemorrhage	3	—	6
Induction	2	24	—

IUGR = Intra Uterine Growth Retardation

PROM = Premature Rupture of the Fetal Membranes

pressure (CPAP) treatment with a face chamber (1). Intermittent positive pressure ventilation (IPPV) was started in infants with recurrent apnea with bradycardia and/or persistent severe hypoxia despite high inspired oxygen concentration and CPAP treatment (12, 20).

During the whole intensive care treatment, the parents were encouraged to visit their baby daily or as often as possible. They also took active part in the nursing care, e.g. feeding their baby with the mother's own breastmilk via gastric tube, even during the intensive treatment period when the baby was treated with CPAP or IPPV.

Table II. *Neonatal data and events.*

	Vaginal delivery	Cesarean section
Total number	29	43
Boys/girls	18/11 (62/38%)	23/20 (53/47%)
Birth weight (g)		
Mean	1 126	1 195
Range	680–1 500	640–1 500
Gestational age (week)		
Mean	29.1	31.2
Range	29–36	26–35
SGA (less than -2 S.D.)	3 (10%)	14 (32%)
Asphyxia		
Short (Apgar score <7 at 1 min)	15	23
Prolonged (Apgar score <7 at 10 min)	10 (34%)	13 (30%)
Respiration difficulties		
IRDS	16 (55%)	13 (30%)
AR	3	8
Assisted ventilation	23 (79%)	22 (51%)
Neonatal mortality (0–28 days)	8 (28%)	11 (26%)
Lethal malformations	—	3

IRDS = Idiopathic Respiratory Distress Syndrome

AR = Respiratory Insufficiency with Recurrent Apnea

SGA = Small for Gestational Age

Follow-up examinations. When the intensive care treatment had finished and the baby had attained a weight of about 2 000 g, he or she was admitted to our intermediary care ward in the Maternity Hospital allowing the mother to stay in hospital for a period before taking her baby home. These babies and their family thus leave the maternity hospital precisely as any healthy normal baby and family.

Before discharge, ophthalmological and neurological examination (including sonocephalogram, electroencephalogram) were performed. All infants were checked every 4th–5th month with neurodevelopmental evaluations in our special follow-up clinic up to at least age two years. Thereafter they were controlled within the Child Health Services once a year. At age 14 months, audiological tests with audiometry were performed.

RESULTS

According to delivery method, the material is divided into two groups: one, 29 infants vaginally delivered and one, 43 infants cesarean section delivered. The indication of cesarean section was preterm breech presentation in 14 cases and obstetric complications in the other 29. Twenty-six of 72 deliveries were induced, two by the vaginal route due to signs of intra-uterine infections. Table I gives details of the obstetric histories.

All infants in breech presentation and all intrauterine growth retarded infants, except three, were delivered by cesarean section. Five patients with vaginal hemorrhage were delivered vaginally. Three had abruptio placentae diagnosed after delivery; two had partial placenta praevia. Two patients with sign of in-

Table III. Autopsy findings in infants dying in the neonatal period.

Add. pregnancy complications	Onset of delivery	Gest. age week	Birth weight (g)	Autopsy findings
Vaginal delivery				
B.L. Cerclage 25 week	Preterm lab, CS	29	1 320	Sepsis
B.F. —	Pre term lab	27	900	ICH (terminal vein) Intrapulm. hem.
K.T. Vaginal hemorrhage + i.u. infection	PROM 2 weeks	26	740	IVH + HMD Myocardio-pathia
I.F. Vaginal hemorrhage Cerclage 26 week	Hemorrhage, CS	29	970	IVH
L.K. Vaginal hemorrhage	PROM 14 h	28	800	HMD
A.H. —	PROM 76 h	29	1 200	IVH + HMD
A.P. —	Pre term lab	26	680	IVH + HMD
J.S. Vaginal hemorrhage + i.u. infection	PROM 1 week?	26	1 010	IVH + Intra- pulmonar hem.
Cesarean section				
A.N. Cerclage 14 week + i.u. infection	PROM 48 h	26	820	HMD
I.A. Preeclampsia IUGR	Ind.	34	1 250 (SGA)	Multicystic kidneys VOC
R.S. Transverse lie	PROM 1 week, CS	31	1 000 (SGA)	IVH + Sepsis
M.G. Preeclampsia IUGR	Ind.	29	740 (SGA)	HMD
P.K. IUGR	Ind.	36	910 (SGA)	Potter's syndrome
I.P. Rh-immunization	Ind.	26	1 100	Hydrops fetalis
L.E. IUGR	Ind.	29	640 (SGA)	HMD + sepsis
A.S. Preeclampsia	Ind.	31	1 340	HMD
K.P. Abruptio placentae	Hemorrhage	30	1 290	HMD + sepsis
L.H. Rh-immunization	Ind.	32	1 500	Hydrops fetalis IVH
M.E. Cerclage 29 week	Ind.	32	1 200	Arnold Chiari's syndrome

IUGR = Intra uterine growth retardation, PROM = Premature rupture of membranes

IVH = Intra ventricular hemorrhage, HMD = Hyaline membrane disease

IND = Induction, CS = Corticosteroid prophylaxis

trauterine infection were delivered vaginally. No intrapartal death occurred.

The cesarean sections were in most cases uncomplicated; but in three, the incision in the lower uterine segment was inadequate, and a T-extension had to be performed.

Neonatal outcome. In the total material, the mean gestational age was 30.2 weeks and the mean birth weight 1 160 g. Seventeen of 72 infants were small for gestational age. Table II lists various neonatal events. The vaginally delivered group had more boys than the cesarean. The birth weights did not differ, but the mean gestational age was somewhat higher in the cesarean group; in accordance with this, also the rate of SGA infants in the cesarean group. The rate of 10-minute asphyxia (Apgar score below 7) was 34% in the vaginally delivered and 30% in the cesarean

group. The rate of IRDS was 55% and 30% and the need for assisted ventilation 79% and 51%, respectively.

During the neonatal period (day 0–28) 19 infants (26%) died. Table III gives data of these infants. All eight vaginally delivered infants that died were born before the onset of the 30th week of gestation. At autopsy four of these infants had hyaline membrane disease (HMD) and two lung hemorrhage. Intraventricular hemorrhage (IVH) was found in five infants. In the cesarean section group five newborns had signs of HMD at autopsy. Three infants died from lethal congenital malformations and two from severe rhesus immunization with hydrops fetalis. IVH was found in two cases, one in combination with hydrops fetalis and one of transverse lie. The neonatal survival rate in the whole material of VLBW infants is 77% (infants with lethal malformations excluded).

Table IV. *Neurological sequelae in surviving infants.*

Add. obstetric complications	Way of delivery	Gest. age	Birth weight	Diagnosis
A.D. —	Vaginal	29	1 080	Diplegia
M.A. Abruptio placentae	Vaginal	31	1 200	Hemiplegia
D.W. Vaginal hemorrhage	Vaginal	29	990	Diplegia
K.P. —	Vaginal	26	790	Retrolental fibroplasia
M.B. Preeclampsia	Section	27	820	Moderate p.m.r.
J.K. Breech	Section	34	1 400 (SGA)	Moderate p.m.r.

p.m.r. = psychomotor retardation

Follow-up. All surviving 53 infants have taken part in the follow-up program, 2–5 years. Six of them have developmental or neurological abnormalities. Table IV lists the data. Three of the vaginally delivered infants suffered from cerebral palsy, and one from monolateral retrolental fibroplasia. In the cesarean section group, two are moderate psychomotor retarded. One was SGA born in 34th week with birth weight 1 400 g, the other was born in 27th week with birth weight 820 g. At age one year, 47 of 53 surviving infants (88%) are completely normal neurological survivors.

DISCUSSION

A restrictive attitude to cesarean section for fetal reasons in deliveries with an infant weighing less than 1 500 g has been predominant. Kubli reported in 1976 that less than 25% of 71 European Departments were ready to perform cesarean section for fetal reasons before the 32nd week and less than 10% before the 30th week (11). With improved neonatal management and prognosis of these infants a reevaluation of this can be considered (10). The challenge for the obstetricians is to determine the ideal proportion of cesarean section and vaginal deliveries in this heterogeneous group of patients.

To find the ideal proportion, randomized, prospective trials with long-term follow-up studies should be done but are difficult to perform. Furthermore, each of these cases is, in a way, unique and the origin of the impending preterm delivery or the complication demanding preterm delivery is various. To get pairs of comparable cases delivered by the vaginal versus abdominal route seems difficult even if the gestational age and birth weight are similar.

Several factors are apparently important in the choice of delivery method. Infants in breech presentation delivered by cesarean section seem to have a more favorable outcome at birth (4) and at long-term follow-up (9) than vaginally delivered. Intrauterine

growth retardation and signs of intraparturial asphyxia are other factors that could justify a cesarean section (17, 19).

The present investigation is a report of the results with a quite rigid policy for delivery of very tiny infants. According to this policy, cesarean section was performed if the fetus was in presentation other than vertex, or if severe additional complications were involved. The results show that this policy was followed quite strictly (see Table I). The policy led to cesarean section in 60% of all deliveries. The neonatal mortality was equal in the two groups. However, the autopsy findings differed considerably. Of the 11 dead infants in the cesarean section group, lethal malformation (3 cases) and hyaline membranes disease (5 cases) were the dominant causes of death. In the vaginally delivered group, hyaline membrane disease was found in four of eight infants and lung hemorrhage in two cases. On the other hand, intracranial hemorrhages were found in six of eight dead infants compared with only two of 11 in the cesarean section group.

It has been reported that IVH is the main threat to tiny newborns during vaginal delivery (6). Several possible mechanisms could be responsible for this condition. Asphyxia due to cord compression or delay in delivery of the head predisposes to IVH (16). The importance of changes in cerebral blood flow related to intraparturial trauma or asphyxia resulting in cerebral ischemia and later brain swelling has shown the special vulnerability in preterm infants (14). These possible etiological factors could be limited by cesarean section. Haesslein & Goodlin (6) reported a more than half incidence of IVH in VLBW infants in cephalic presentation after cesarean section. A considerable reduction of IVH has also been reported after cesarean section in preterm breech presentation (9).

However, cesarean section does not always eliminate the risk of delivery trauma, as technical problems can appear when the tiny infant must be ex-

tracted through the uterine incision. Therefore, classical incision has been recommended (6). In the present study, three cases of a T-extension of the transverse incision have been performed. The administration of terbutaline in a bolus injection just before opening the uterine cavity seemed to facilitate the extraction of the infant and might be another approach to manage this problem.

Long-term follow-up is of major importance in the evaluation of perinatal care of VLBW infants. In the present study, follow-up 2–5 years of age showed that three of 21 surviving infants in the vaginally delivered group had cerebral palsy and one suffered from retrolental fibroplasia. In the cesarean section group, only two of 32 surviving infants had any signs of neurological sequelae. Intraventricular hemorrhage at autopsy and cerebral palsy at follow-up were more common among the infants vaginally delivered compared to those delivered by cesarean section. The vaginally delivered infants had a lower birth weight and were more preterm than the infants in the cesarean section group. On the other hand, the SGA-diagnoses were overrepresented (one third of all infants) in the cesarean section group. For these reasons a comparison of the results in the two groups is uncertain. However, a liberal attitude to cesarean section seems to be justified. Whatever additional advantages for VLBW infants can be achieved by increasing the cesarean section group needs further investigations.

During the last decade the prognosis for very low birth weight infants has improved considerably (15, 18). For example, during 1971–1974 the mortality rate of singleton infants weighing less than 1500 g at our clinic was 45% and the survivors had neurological sequelae in 18%. During that period the rate of cesarean section was 11% (13).

The favorable short-term and long-term outcome in the present study is encouraging. The result emphasizes the value of a close cooperation between obstetricians and neonatologists.

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MODE OF DELIVERY IN THE LOW BIRTH WEIGHT FETUS IN VERTEX PRESENTATION.
A PAIRED CONTROLLED STUDY WITH LONG-TERM FOLLOW-UP

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ABSTRACT

In a paired controlled multicenter study of patients in preterm labor of unknown etiology without additional maternal or fetal complications 59 low birth weight infants in vertex presentation delivered vaginally were compared to 59 infants delivered by cesarean section.

In the early postpartum period hypothermia and acidosis occurred more often in the vaginal delivery group. The rate of respiratory disorders and need for assisted ventilation did not differ between the groups. Persistent ductus arteriosus occurred in 19 % in the vaginal delivery group and in 7 % in the abdominal delivery group. At follow-up until 18-24 months of age the rate of cerebral palsy did not differ between the groups whereas the rate of psychomotor retardation was significantly higher in the vaginal delivery group ($p < 0.05$).

The difference in percentage of total outcome, i.e. sum of mortality and neurodevelopmental sequelae, being 20.3 % in the vaginal delivery group versus 8.5 % in the cesarean section group fails to reach a statistical significance, but the results suggest that vaginal delivery can be more hazardous for the low birth weight infants than abdominal delivery.

INTRODUCTION

The improved survival rate of preterm infants in later years has incited growing interest in obstetric management of preterm deliveries (1-8). The small preterm infant is vulnerable. Various events during labor are potentially dangerous both for survival and later neurodevelopment. The route of delivery for preterm infants is still a matter of great concern and a controversial question.

For preterm infants in breech presentation strong evidence has been presented in recent years for routine cesarean section (9-11). On the other hand the best way of delivery for the preterm fetus in vertex presentation has not been settled. In the present investigation our aim has been to evaluate the fetal outcome in relation to the mode of delivery by a matched control study of preterm deliveries.

PATIENTS AND METHODS

The present material was collected between 1975 and 1980 in the Departments of Obstetrics and Gynecology, University Hospital, Lund, the Community Hospital of Helsingborg (in total 30 138 deliveries) and the Perinatal Unit, Women's College Hospital, Toronto (19 000 deliveries). Antepartum and intrapartum records of all mothers delivered by cesarean section of an infant weighing less than 2 000 grams were reexamined, and those fulfilling the following criteria were included in the study: singleton pregnancy, preterm labor of unknown etiology, no additional maternal complication (i.e. no other maternal disease, no signs of preeclampsia, infection, anemia, vaginal bleedings or abruptio placentae) and no additional fetal complications (e.g. intrauterine growth retardation, abnormalities of the fetal heart rate or congenital malformations).

The matched controls, all vaginally delivered in vertex presentation and fulfilling the above mentioned criteria, were chosen as follows: 1. delivery in the same gestational week, 2. birth weight within $\pm$ 200 grams, 3. delivery in the same obstetrical department, 4. neonatal treatment in the same neonatal intensive care unit, 5. delivery date within the preceding or following 6 months.

These criteria were fulfilled by 35 Swedish and 24 Canadian pairs. Twenty-six pairs consisted of infants weighing between 1 000 and 1 500 grams and four of infants weighing less than 1 000 grams at birth. As shown in Table I preterm breech presentation and previous cesarean section were the most common causes for delivery by cesarean section.

Table I.
Indications for cesarean section

Breech presentation	38
Previous C.S.	7
Transverse lie	5
Others*	9
Total	59

* POH, previous myomectomy, elderly primigravida, marginal placenta.

The main principles for management of preterm labor and delivery were the same in the three departments. They have been described in detail previously (12, 13). Gestational age was assessed from the menstrual history and by means of repeated clinical and ultrasonic examinations. For inhibition of preterm labor - beta-receptor stimulators (isoxsuprine in Toronto and terbutaline in Lund/Helsingborg) were administered. Corticosteroid prophylaxis was usually given to mothers with intact membranes in impending preterm delivery.

During vaginal delivery electronic heart rate monitoring was routinely performed. Spontaneous delivery occurred in 45 of the 59 vaginally delivered patients. Fourteen patients, all delivered at the Women's College, were delivered by low outlet forceps. For analgesia at cesarean section epidural block was used in 15 and general anesthesia in 44 cases. A transverse incision in the lower uterine segment was performed in 52 of 59 cesarean sections and the remaining 7 underwent classical vertical incision.

Every preterm delivery was attended by a pediatrician. The baby was immediately placed on the resuscitation table under radiant warmer and covered with prewarmed towels during the initial observation and Apgar scoring period. In cases with clinical signs of asphyxia supplemental oxygen was administered. When required ventilation with mask and bag (Swedish material) or nasal intubation (Canadian material) was the routine procedure for resuscitation. In every other aspect the initial neonatal care was equal in both populations, i.e. thorough regulation of environmental temperature to avoid heat loss, early prevention of acidosis and hypoglycemia, early supply of i.v. fluid and treatment with continuous positive airways pressure (CPAP) and/or intermittent positive pressure ventilation (IPPV) in infants with respiratory insufficiency. Soon after birth all infants were transferred to the neonatal intensive care unit (NICU) adjacent to the delivery ward.

The neonatal intensive care principles have been described previously (14, 15). The diagnostic criteria for respiratory disorders (i.e. idiopathic respiratory distress syndrome (IRDS) or hyaline membrane disease, wet lung syndrome or transient tachypnoea, apnea repetens (AR) or recurrent apnea of immaturity) as previously described in a large multicenter study (16) have been applied in the present material.

All surviving infants, except seven Canadian, were reexamined at 5-6,

9-11 and 18-24 months of age regarding morbidity and neurodevelopmental handicaps. The seven Canadian infants who were not reexamined had all a birthweight above 1 500 g and were classified as normals at discharge from NICU.

The cerebral palsy syndromes observed in the present material were transient dystonia, persistent hypotonia, diplegia or hemiplegia. Infants judged by clinical examination to have psychomotor retardation (PMR) showed obvious delay of early neuromuscular development and in their later ability e.g. to sit, walk and in speech development taking into account the degree of prematurity at birth, i.e. the development was calculated according to age adjusted for prematurity as judged by maternal dates and neonatal maturity assessment at birth. Infants with developmental delay more than 2 months (at 5-6 months of age), more than 3 months (at 9-11 months of age) and more than 6 months (at 18-24 months of age) were assessed as infants with PMR. Specific psychological tests were not performed in this study. Ophthalmological examination and audiometry tests were made at 10-14 months of age.

Postmortem examination was performed in all but one of the infants who died. The infant mortality rate includes both neonatal (1 to 28 days) and postneonatal (29 days to 1 year) deaths.

The two groups were compared using Fisher's exact probability test for independent groups.

RESULTS

Table II shows maternal data in both study groups. There was no significant difference between the vaginally and abdominally delivered groups in maternal age, obstetric history, administration of beta-agonists, corticosteroid prophylaxis, onset of delivery or duration of hospitalization before delivery. Hospitalization after delivery was, however, prolonged for mothers delivered by cesarean section ($p < 0.01$).

Neonatal period

Neonatal data are presented in Table III and Table IV. The boy/girl ratio was 0.7 in the cesarean group and 1.7 in the vaginally delivered group. The mean birth weight was 1 558 gram in the cesarean section group and 1 566 gram in the vaginally delivered group. Four infants in the vaginal

Table II.

Maternal data	Cesarean section n = 59	Vaginal delivery n = 59
Age (years, mean)	27.3	27.0
Gravidity (mean)	2.6	2.1
Parity (mean)	0.9	0.6
Previous preterm delivery	6	7
Previous spontaneous abortion	17	11
Previous induced abortion	4	4
Administration of betaagonists*	48	43
Corticosteroid prophylaxis [†]	35	31
Onset of delivery		
Preterm labor	37	41
PROM	22	18
Hospitalization before delivery (days, mean)	5.6	6.2
Hospitalization after delivery (days, mean)	7.4	3.9

* terbutaline in Lund/Helsingborg, isoxsuprine in Toronto

[†] betamethasone

PROM = premature rupture of the fetal membranes (> 24 h)

delivery group and three in the cesarean section group had birth weight close to the lower level (-2 S.D.) in relation to gestational age. All other infants had birth weight appropriate for gestational age.

Low one minute Apgar scores were more common among cesarean born infants (61 % versus 39 %). There was no difference between the groups in the ten-minutes Apgar score. At admittance to the NICU 41 % in the vaginal delivery group had pH less than 7.25 but only 24 % in the cesarean section group. Nevertheless there was no statistically significant difference between the groups in the rate of acidosis. One vaginally born infant had hypoglycemia (< 1.0 mmol/l). Hypothermia occurred in five vaginally born and in none cesarean section born infants ($p < 0.05$).

The incidence of idiopathic respiratory distress syndrome (34 % versus 32 %), wet lung (27 % versus 32 %) and respiratory insufficiency with recurrent apnea (6 % versus 12 %) did not differ between the study groups

Table III.

Neonatal data and laboratory status at admittance to NICU

	Cesarean section n = 59	Vaginal delivery n = 59
Boys/girls	24/35	36/23
Birthweight (g)		
Mean (1 S.D.)	1558 $\pm$ 325	1566 $\pm$ 320
Asphyxia		
Short (Apgar score < 7 at 1 min)	37	22
Prolonged (Apgar score < 7 at 10 min)	3	2
Acid-base balance, pH	n = 53	n = 49
Mean (1 S.D.)	7.29 $\pm$ 0.10	7.26 $\pm$ 0.07
Acidosis (pH < 7.25)	13	20
Base deficit (< -10 mmol/l)	9	14
Blood glucose (mmol/l)	n = 53	n = 57
Mean (1 S.D.)	2.4 $\pm$ 1.0	2.8 $\pm$ 1.5
Hypoglycemia (< 1 mmol/l)	1	-
Temperature (Celsius)	n = 54	n = 57
Mean (1 S.D.)	36.2 $\pm$ 0.5	35.9 $\pm$ 0.6
Hypothermia (< 35.0 °C)	-	5

(Table IV). The duration of supplemental oxygen and assisted ventilation treatment was equal in both groups.

Persistent ductus arteriosus was diagnosed in four infants (6.7 %) in the cesarean section group and in 11 infants (18.6 %) in the vaginal delivery group. All but one were treated successfully. Persistent fetal circulation occurred in three cesarean section born infants. Septicemia occurred in 7 cesarean section (12 %) and in 9 vaginally (15 %) born infants. No case of necrotizing enterocolitis was diagnosed.

Seizures occurred in four cesarean section and in six vaginally born infants in the neonatal period. Intracranial hemorrhage was diagnosed in five out of these ten cases (i.e. bulging fontanelle, cerebrospinal fluid hemorrhage and deteriorating clinical condition). Five of these ten infants

Table IV.

Neonatal respiratory difficulties and assisted ventilation

	Cesarean section n = 59	Vaginal delivery n = 59
Respiratory difficulties		
IRDS	20	19
Wet lung	16	19
AR	3	7
Assisted ventilation		
IPPV	16	19
duration (days, mean)	13.9	11.6
CPAP	28	26
duration (days, mean)	5.2	5.0
Oxygen	42	43
duration (days, mean)	17.5	16.3

IRDS = idiopathic respiratory distress syndrome

AR = respiratory insufficiency with recurrent apnea

IPPV = intermittent positive airways pressure

CPAP = continuous positive airways pressure

died and three developed neurological handicaps.

Three infants (2 vaginally and 1 cesarean section born) died in the neonatal period (see Table V).

Follow-up

Two infants died in later infancy (Table V). One infant born by cesarean section had IRDS, septicemia and meningitis in the neonatal period. Later he developed hydrocephalus and died at two months of age. One vaginally born infant with IRDS and PDA needed IPPV treatment for 77 days. He was severely psychomotor retarded at 5-6 months of age and died in sudden infant death at 8 1/2 months of age.

The rate of neurodevelopmental abnormalities at 5-6, 9-11 and 18-24 months of age in the two study groups is presented in Table VI. At 5-6 months of age 15 infants demonstrated sequelae. At 18-24 months three of

Table V.
Obstetrical and neonatal data of the dead infants

Case	Onset of delivery	Mode of delivery	Gestational age (wks)	Sex	Birthweight (g)	pH *	Temp *	Neonatal diagnoses	Neonatal seizures	Assisted ventilation	Length of life	Post-mortem examination
1.	PROM	vaginal	32	♀	1600	7.21	35.4	IRDS	+	IPPV (2 d.)	2 d.	HMD + bilateral IVH
2.	labor	vaginal	29	♀	1320	7.18	34.3	IRDS	+	IPPV (2 d.)	2 d.	HMD + bilateral IVH
3.	labor	sectio	26	♀	800	7.38	35.7	IRDS	+	IPPV (5 d.)	7 d.	refused PM
4.	labor	sectio	30	♂	1290	7.22	35.2	IRDS + meningitis septicemia	+	CPAP (3 d.)	2 m.	IVH + hydrocephalus
5.	labor	vaginal	29	♂	1000	7.12	35.2	IRDS + PDA	+	IPPV (77 d.)	8 1/2 m.	IVH + PDA* + BPD

Abbreviations see table IV.

HMD = hyaline membrane disease

IVH = intraventricular hemorrhage

BPD = bronchopulmonary dysplasia

PDA = persistent ductus arteriosus

* At admittance to NICU

Table VI.

Neurodevelopmental abnormalities at the follow-up study

	5 - 6 months		9 - 11 months		18 - 24 months	
	CS	VD	CS	VD	CS	VD
	n=54	n=53	n=54	n=52	n=54	n=52
Cerebral palsy						
Transient dystonia	2	1	0	1	0	0
Persistent hypotonia	1	0	1	0	0	0
Diplegia	1	1	2	3	2	3
Hemiplegia	1	0	1	0	1	0
Psychomotor retardation	1	7*	0	5*	0	6*
Total	6	9	4	9	3	9

* $p < 0.05$

CS = cesarean section

VD = vaginal delivery

these infants were normal but handicaps persisted in 12 children, three infants in the cesarean section group (5.6 %) and nine infants in the vaginal delivery group (17.3 %). Psychomotor retardation without cerebral palsy occurred significantly more often in the vaginally delivered group compared to the abdominally delivered group ($p < 0.05$). Table VII gives obstetrical and neonatal data of these infants.

During the follow-up period chronic lung disease (bronchopulmonary dysplasia) occurred in one cesarean section and three vaginally born infants. Obvious disturbance in parent-infant relationship was observed in two cesarean section and in five vaginally born infants. Ophthalmological follow-up revealed no cases of retrolental fibroplasia. Minor hearing loss was present in two psychomotor retarded infants in the vaginal delivery group.

The percentage of the total outcome i.e. the sum of mortality and neurodevelopmental sequelae rate, was 8.5 % in the cesarean section group and 20.3 % in the vaginally born group of preterm infants ($p < 0.07$).

Table VII.

Obstetrical and neonatal data of the infants with neurodevelopmental handicaps at 18-24 months of age

Case	Onset of delivery	Mode of delivery	Gestational age (wks)	Sex	Birthweight (g)	pH *	Temp	Neonatal diagnoses	Neonatal seizures	Assisted ventilation	Developmental and neurological sequelae
1.	labor	vaginal	33	♂	1440	7.24	35.6	AR + PDA	-	IPPV (5 d.)	PMR
2.	labor	vaginal	32	♂	1480	7.20	35.8	IRDS + septicemia	+	CPAP (4 d.)	PMR + diplegia
3.	labor	vaginal	28	♂	900	7.10	34.9	IRDS + PDA	+	IPPV (28 d.)	PMR
4.	labor	vaginal	34	♂	1980	7.31	35.5	pneumonia + septicemia	-	IPPV (10 d.)	PMR
5.	labor	vaginal	31	♂	1610	7.28	37.0	AR	-	CPAP (1 d.)	Mild diplegia
6.	labor	vaginal	31	♂	1480	7.16	37.0	IRDS + PFC	-	IPPV (6 d.)	PMR
7.	labor	vaginal	32	♀	1690	-	36.3	wet lung	-	-	PMR
8.	labor	vaginal	35	♀	1840	-	36.5	-	-	-	PMR + general hypotonia
9.	labor	vaginal	32	♂	1740	7.20	35.3	wet lung	-	-	Diplegia
10.	PROM	sectio	30	♀	1300	7.21	36.6	wet lung + PDA	-	CPAP (2 d.)	Mild diplegia
11.	labor	sectio	27	♀	1170	7.34	-	IRDS	+	IPPV (8 d.)	Hemiplegia
12.	labor	sectio	31	♂	1750	7.26	36.5	wet lung + septicemia	-	CPAP (1 d.)	Diplegia

Abbreviations see tables IV and V.

PMR = psychomotor retardation

PFC = persistent fetal circulation

* At admittance to NICU

DISCUSSION

In the literature some authors have presented data suggesting that for very low birth weight infants in vertex presentation cesarean section might be the delivery method of choice. Thus Stewart and Reynolds (1974) (17) reported lower mortality rate in cesarean section born infants with birth weight less than 1 500 g. Smith et al (1980) (6) found a 35 % survival rate in vaginally born infants with birth weight 750-1 000 g compared to 80 % in infants born by cesarean section. No difference was found in infants weighing more than 1 000 g. Similar results were presented by Bowes (1981) (8). Berg and Lindberg (1980) (18) have shown that cesarean section was beneficial in preterm delivery before 32 weeks of gestation with intra-uterine asphyxia. They also found a lower incidence of neurological sequelae in comparison to vaginal preterm deliveries.

These authors stated that conclusive evidence could not be obtained from these materials because of uneven distribution of maternal and fetal complications in the various groups. In these materials the cesarean section was often performed for some additional reason, which could *per se* influence the results. In order to avoid such a bias, we decided to perform a paired matched control study of patients in preterm labor without additional complications. However, patients delivered preterm by cesarean section and without complications are rare, which is illustrated by the fact that we had to go through 49 000 deliveries to obtain 59 pairs. The groups were well matched with regard to maternal factors and birth weight. There were more boys in the vaginal delivery group, which might be a negative factor.

A higher incidence of one minute Apgar score below 7 was found in cesarean section born infants which is in agreement with other reports (6, 19). This initial neonatal depression seems to be temporary as there was no difference in Apgar score at 10 minutes. Smith et al (6) suggested that the lower Apgar score in cesarean section born preterm infants is a transient effect of anesthesia and the absence of the stimulatory action of a vaginal delivery.

Hypothermia and acidosis in the early postpartum period occurred more often in vaginally born than in infants born by cesarean section. The immediate postpartum care and the transport technique of the neonate to the NICU should not differ between the two groups. Still, one must consider the practical problems in obtaining optimal perinatal care at a vaginal delivery, which may be the cause of the significantly higher incidence of

hypothermia among these infants. These problems are often easier to manage at a cesarean section i.e. the exact time of delivery can be planned and measures for optimal perinatal care can be taken in advance. Furthermore, the high rate of acidosis in vaginally born infants (34 % versus 15 %) in the early post-partum period indicates that these infants might have been in distress already before birth. This had been confirmed in a recent study (20) where preterm infants were followed by repeated pH assessments during vaginal delivery. In infants before the 34th week of gestation 52 % had a scalp pH less than 7.25. At birth 35 % had a pH less than 7.20 in umbilical artery samples. Moreover Low et al (21) in an analysis of intrapartum intensive care reported a 24 % incidence of fetal metabolic acidosis (buffer base less than 36.1 mEq/l in umbilical artery) in infants with fetal weight greater than the crossover weight for each week in week 30-32. Thus, the immature with its concurrent complications is at considerable risk of developing intrapartum acidosis.

Earlier studies have demonstrated an association between preterm abdominal delivery and an increased incidence of IRDS (22, 23). In the present study we could not verify this as the incidence of respiratory difficulties and need for assistant ventilation were equal in the abdominal and vaginal delivery group. Similar results have been reported also by other authors (7, 24).

All five infants who died in the present study had IRDS and IVH. Both disorders are well-known consequences of severe distress in the intrapartum and early postpartum period. A close association between IRDS and IVH has been proven although IVH is rare after 30 weeks of gestation (25).

At follow-up until at least 18 months of age three infants in each group had cerebral palsy. However, psychomotor retardation occurred significantly more often in the vaginal delivery group ($p < 0.05$). The cause for the high rate of psychomotor retardation after vaginal preterm delivery in our study is not clear. Several factors may be considered. Due to the soft skull of preterm babies it is impossible to avoid a certain amount of cerebral trauma at vaginal delivery. Kosmetatos et al (26) in their study of mostly vaginally born infants weighing less than 1 500 g found a 58 % incidence of IVH diagnosed by serial computerized tomography. In vaginal delivery the soft cranium of the preterm infant is exposed to uterine contractions causing pronounced changes in intracranial pressure in comparison to term infants with a rigid skull. When the head is in the birth canal the blood pressure inside the capillaries will be increased by 40-60 mm Hg (27). Ana-

logous findings were seen in preterm lambs, where a combination of acidosis and imposed fluctuations in cerebrovascular transmural pressure may start bleedings into the germinal layer and ventricles (28).

The present result demonstrate that vaginally born preterm infants are at high risk to develop hypothermia and acidosis in the early postpartum period. At long-term follow-up the vaginally born infants were more often than cesarean section born infants psychomotor retarded. Further follow-up into preschool and school age is necessary to evaluate whether their developmental handicap is transitory or permanent.

The difference in percentage of total outcome (20.3 vs 8.5 %) between the two groups fails to reach a statistical significance, but the results suggest that vaginal delivery can be more hazardous for the low birth weight infants than abdominal delivery. Further prospective, controlled randomized studies are required to settle the question if a general use of cesarean section should be advocated in these deliveries.

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Intrapartum Fetal Monitoring in Preterm Deliveries: Prospective Study

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Fetal heart rate (FHR) and fetal acid-base status were prospectively studied in 61 patients in preterm labor of unknown etiology. Tachycardia (43%), decreased variability (39%), and variable decelerations (61%) were often recorded. Fetal acidosis (pH less than 7.25 in scalp blood) occurred in 52% of patients delivered in weeks 28 to 33 and in 8% of patients delivered in weeks 34 to 36 of gestation. Ominous FHR changes considered classic for fetal distress were very frequently associated with fetal acidosis, but among the most immature infants with fetal acidosis several had tachycardia and decreased variability combined with variable decelerations of innocent appearance. Patients treated with a β -receptor agonist (terbutaline) for inhibition of preterm labor had fetal tachycardia and decreased variability more often than nontreated patients. No positive correlation with fetal acidosis for these FHR changes could be demonstrated in the terbutaline-treated patients. The results indicate that fetal acidosis can appear rapidly and frequently among the most immature infants during labor, and emphasize the value of considering the gestational age and the administration of β -receptor stimulants in the assessment of the FHR pattern in preterm labor. (*Obstet Gynecol* 60:99, 1982)

The improved prognosis for preterm infants during recent years has focused interest on the obstetric management of these deliveries.¹⁻³ Several clinics report favorable results after changing from a nonintervention policy to more active management. Preterm infants seem to be vulnerable during delivery, and intrapartum distress is associated with a large rate of intrapartum deaths,⁴ respiratory failure,⁵ and intraventricular hemorrhage.⁶

For diagnosis and prevention of asphyxia, continuous electronic monitoring is strongly recommended in preterm deliveries. Data provided by Paul and associates⁷ reveal that intrapartum fetal monitoring seems to have its greatest value in preterm deliveries. However,

in clinical practice, difficulties often appear in assessing the fetal heart rate (FHR) tracing of the preterm infant.⁸ Does the preterm infant respond to stress in the same way as the term infant? Could the obstetrician use the same criteria in the assessment of the FHR tracing regardless of gestational age?

Most available studies of fetal monitoring in preterm deliveries have analyzed whether the FHR tracing could be related in a predictive way to the neonatal outcome. Hobel and associates⁵ and later Martin and associates,⁹ in studies of low birth weight infants, suggested that ominous FHR changes were associated with an increased incidence of respiratory failure and neonatal mortality. More recently, Bowes and colleagues,¹⁰ in a study of 61 infants weighing less than 1500 g, concluded that lack of baseline variability and the occurrence of late decelerations were predictive of fetal acidosis. Their study also suggested that prompt intervention after ominous FHR changes reduces serious sequelae of fetal acidosis.

So far few studies have correlated FHR changes during preterm delivery with fetal scalp pH. Hobel and associates,⁵ in a study of 25 low birth weight infants, and Zanini and associates,¹¹ in a retrospective study of 62 preterm infants, demonstrated an association between abnormal FHR patterns and fetal acidosis and suggested that FHR patterns were related to preterm fetal pH in a manner similar to that reported in studies of mature fetuses.

At the Department of Obstetrics and Gynecology of the University Hospital in Lund, electronic fetal monitoring and pH measurements are routinely used.¹² In the present investigation the authors studied prospectively the relationship between FHR changes and fetal acid-base status and evaluated the incidence of fetal asphyxia in preterm vaginal deliveries.

Materials and Methods

The study subjects were 61 patients, all delivered before term during 1979 and 1980 at the Department of

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Obstetrics and Gynecology of the University Hospital in Lund. All patients had undergone routine prenatal care at maternity welfare centers every 4 weeks from the 12th week and every 2 weeks from the 20th week on. Ultrasound examinations were performed in 56 of the 61 patients before admission to the hospital. At admission to the delivery ward, gestational age was determined from date of the last menstrual period and by the clinical and ultrasound examinations. Using data from the prenatal care together with current data after admission, one of the authors (II, MW) classified the mother and infant.

All subjects fulfilled the following criteria: gestational age less than 37 weeks, singleton pregnancy, cephalic presentation, preterm labor of unknown etiology, no additional maternal complications (no other maternal diseases, signs of preeclampsia, anemia, or vaginal bleeding), and no additional fetal complications (biparietal diameter within 2 SD, normal symphysis-fundus distance).

Patients in preterm labor with intact membranes were treated by bed rest and administration of terbutaline as previously described.¹³ Corticosteroid prophylaxis was given to patients in the 28th to 35th weeks of gestation with intact membranes when it was probable that delivery could be delayed more than 48 hours.

Patients with rupture of the membranes were conservatively treated by bed rest and terbutaline.¹⁴ Specimens for bacterial and viral isolation were obtained twice a week. No prophylactic antibiotic therapy was given before delivery, but if the patient showed signs of intrauterine infection, ampicillin was given intravenously and the patient was promptly delivered.

All tocolytic treatments were discontinued when the cervix was effaced or almost effaced and dilated at least 4 cm. Then the membranes were artificially ruptured if necessary and all patients were treated as follows: 1) at 4 cm dilatation, a fetal scalp electrode was applied and the FHR was recorded with a Hewlett Packard (8030 A) cardiotocograph; 2) at 5 cm dilatation, the fetal scalp pH was measured; 3) at full dilatation, the fetal scalp pH was measured; and 4) at delivery, acid-base status was measured in the umbilical artery from the clamped cord (before the first breath).

These procedures were performed by one of the obstetricians (II, MW). After delivery, the need for resuscitation and the Apgar score were determined by a neonatologist (PH, NWS). During the initial 30 minutes, the baby was placed in an Isolette radiant heat incubator. Continuous monitoring of heart rate and respiration (Hewlett Packard cardiorespirograph), temperature, and electrocardiogram (ECG) was started immediately after delivery. Acid-base status was measured repeatedly. Thereafter the infant was transferred

to the neonatal intensive care unit for treatment, as described earlier.¹⁵

The FHR tracing recorded at 5 cm to full dilatation was visually assessed according to the criteria of Hamacher et al and Hon.^{16,17} The following variables were assessed: basal line; variability; early, late, and variable decelerations; and accelerations. Combined decelerations were tabulated according to the first component.¹⁸ The intrapartum pH analysis was performed with an International Laboratory (213-01) unit. The acid-base status in the umbilical artery was measured with an International Laboratory (613) unit. Fetal scalp pH values of less than 7.25 were regarded as acidotic. For statistical comparison, the χ^2 and Student *t* tests were used. *P* values above .05 were not regarded as significant.

Results

The material is divided into 2 groups according to gestational age (Table 1). In group A, 23 patients delivered in weeks 28 to 33 of gestation; in group B, 38 patients delivered in weeks 34 to 36 of gestation.

Fetal Heart Rate

Figure 1 shows the FHR baseline. Bradycardia (under 120 beats per minute) was not recorded in any patient in group A but in 2 patients in group B. Tachycardia (over 160 beats per minute) occurred in 18 group A patients (78%) and in 8 group B patients (21%). In group A about half the patients with normal baseline values or tachycardia had fetal acidosis. In group B all

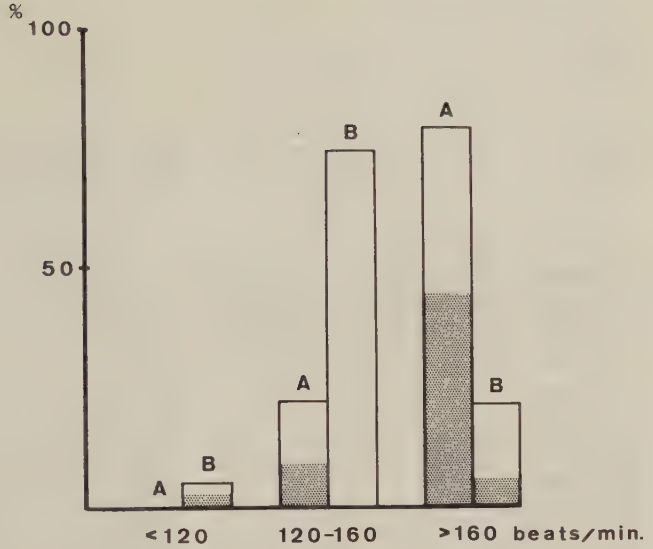
Table 1. Obstetric Data and Events

Data	Group A (28-33 weeks)	Group B (34-36 weeks)
Total number	23	38
Maternal age (yr) (mean $\pm$ 1 SD)	29.3 $\pm$ 5.4	30.4 $\pm$ 4.6
Parity (mean $\pm$ 1 SD)	0.7 $\pm$ 0.7	1.5 $\pm$ 0.9
Onset of delivery		
Preterm labor	19	32
PROM > 24 hr	4	6
Terbutaline treatment*	9	14
Corticosteroid prophylaxis	10	8
Oxytocin augmentation	4	7
Analgesia		
Epidural block	9	10
Pudendal block	20	35
Ketobemidone 0.8-1 ml IM		1
Nitrous oxide	9	20

PROM = premature rupture of membranes; IM = intramuscular.

* Terbutaline infusion discontinued within 8 hours before delivery.

Figure 1. The FHR baseline in group A (28 to 33 weeks) and in group B (34 to 36 weeks). Speckled area = fetal acidosis (pH < 7.25 at 5 cm and/or at full dilatation).



patients with a normal baseline rate had a normal pH value; fetal acidosis occurred only in patients with abnormal baseline rate.

Figure 2 shows the FHR variability. Normal variability (10 to 25 beats per minute) occurred in 10 patients in group A (44%) and in 24 patients in group B (63%). Thirteen patients in group A (57%) and 11 in group B (29%) were found to have decreased variability (5 to 10 beats per minute) or silent pattern (0 to 5 beats per minute). A positive correlation to fetal acidosis could be demonstrated among these patients in group B ($P < .05$) but not in group A. Increased variability or saltatory pattern (over 25 beats per minute) was recorded in 3 36th-week patients, all with a normal fetal pH.

Figure 3 shows the frequency of FHR decelerations. Three patients in group A (13%) and 12 in group B (32%) had no decelerations. Early decelerations occurred rarely, and solely in patients in weeks 35 to 36 of gestation. Late decelerations were recorded in group A in 4 patients (17%) and in group B in 2 patients (5%). All these patients had fetal acidosis except 1 in group A. Sixteen group A patients (70%) and 21 group B patients (55%) had variable decelerations.

An analysis of the variable decelerations of the FHR revealed 3 dominant types (Figure 4, Table 2). A V-shaped uncomplicated variable deceleration was the most common. It had a duration of 10 to 40 seconds and a fast recovery to baseline. Two complicated types

of variable decelerations were observed: a U- or V-shaped deceleration lasting at least 40 seconds with a late component, and a V-shaped deceleration lasting less than 40 seconds followed by an overshoot acceleration. These 2 types occurred with the same frequency (12%) and were in most cases related to a low fetal and umbilical pH value. Table 3 shows the depth of the variable decelerations. In group A, 5 of 9 patients with a loss of 30 to 60 beats and all with a loss of more than 60 beats had a fetal scalp pH of less than 7.25. In group B, only 1 of these patients had fetal acidosis. The mean umbilical artery pH did not differ between groups when the variation was less than 30. However, with more pronounced decelerations, the mean umbilical artery pH was lower in group A than in group B.

Sporadic FHR accelerations (at least 1 acceleration of more than 15 beats per minute in 15 minutes) occurred in 11 group A patients (48%) and in 29 group B patients (76%). Accelerations showed a negative correlation to fetal acidosis in group B ($P < .01$) but not in group A.

To study the relationship between administration of terbutaline and FHR changes, the 2 dominating FHR changes, tachycardia and decreased variability, were plotted against terbutaline treatment (Table 4). In the nontreated group a positive correlation to fetal acidosis for tachycardia and decreased variability was observed, which could not be demonstrated in the terbutaline-treated group.

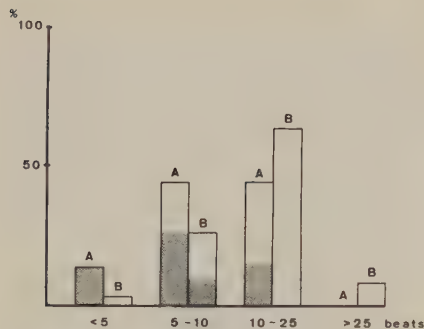


Figure 2. The FHR variability in group A (28 to 33 weeks) and in group B (34 to 36 weeks). Speckled area = fetal acidosis (pH < 7.25 at 5 cm and/or at full dilatation).

Fetal pH

Table 5 shows the mean pH and the incidence of fetal acidosis at 5 cm, full dilatation, and in the umbilical artery. At these stations, the mean pH was significantly lower in group A than in group B. Twelve group A patients (52%) and 3 group B patients (8%) had a fetal scalp pH of less than 7.25. Table 6 gives data of these deliveries. Acid-base status was measured in the umbilical artery in 10 of these patients. Hypercapnia (PCO_2 over 7.0 kilopascals) was demonstrated in 4 infants. Two others had a base deficit above 14 mmoles per liter combined with a normal PCO_2 value.

Six of 12 group A patients and all in group B with fetal acidosis demonstrated ominous FHR changes, such as tachycardia and decreased variability, together with late decelerations or variable decelerations with a

late component. The other 6 group A patients had variable decelerations with short duration (less than 40 seconds), in 4 cases with an overshoot pattern.

Partial abruptio placentae was diagnosed after delivery in 2 of these patients; in 2 febrile illness developed during labor (both had premature rupture of the membranes); in another 2 patients, oxytocin augmentation with suspected overstimulation was observed. The rest showed no obvious explanation for the deranged fetal acid-base balance.

Delivery Data

Fifty-seven patients had a spontaneous vaginal delivery. In 2, outlet forceps were used; in another 2, cesarean section was performed because of fetal distress. All were delivered within 3 hours after 4 cm

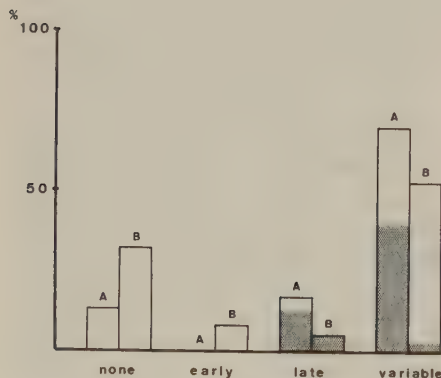


Figure 3. Periodic FHR changes in group A (28 to 33 weeks) and in group B (34 to 36 weeks). Speckled area = fetal acidosis (pH < 7.25 at 5 cm and/or at full dilatation).



Figure 4. The 3 dominant types of variable decelerations. (A) Uncomplicated, (B) late component, (C) overshoot.

dilatation. The mean time from 5 cm dilatation to delivery was 96 minutes in group A and 133 minutes in group B.

Cord complications (nuchal or true knot) occurred in 22% of group A and in 26% of group B patients. Four were found to have partial abruptio placentae, all diagnosed after delivery.

The mean birth weight in group A was 1650 ± 357 g and in group B 2443 ± 332 g. Two infants, both in group B, were considered small for gestational age according to the Swedish standard curve. Apgar scores were generally good; 5 infants had a score of less than 7 at 1 minute; none had less than 7 at 5 minutes. Four of 5 infants with a 1-minute Apgar score less than 7 had fetal acidosis, as shown in Table 6 (cases 6, 7, 8, 15). Two infants died during the neonatal period (3.3%), both of idiopathic respiratory distress syndrome. During labor both demonstrated variable decelerations with overshoot pattern, but had normal pH values.

Discussion

Improved fetal outcome is reported after cesarean section in preterm breech deliveries.¹⁹⁻²¹ Moreover, there is suggestive evidence that cesarean section might be preferable for very low birth weight infants (regardless of presentation) in pregnancies with severe complications.²² Thus the labor and the mode of delivery might be determinant of the preterm infant's chance of surviving and subsequent development.

To eliminate other influencing factors at vaginal

delivery the authors chose, in the present work, to study only patients in preterm labor without additional maternal or fetal complications. To study the influence of delivery at various gestational ages, the material was divided into 2 parts: group A patients in weeks 28 to 33 and group B patients in weeks 34 to 36 of gestation.

The present study recorded tachycardia (78%) and decreased variability (57%) more often among infants delivered at weeks 28 to 33 than among those delivered at weeks 34 to 36 (21% and 29%, respectively). These findings might reflect fetal immaturity, as the basal heart rate and the visually assessed variability (long-term variability) are the results of counteracting activity of the parasympathetic and sympathetic systems,²³ and there is evidence that the parasympathetic system is not fully developed by the 30th week of gestation.²⁴ Fetal tachycardia can also be induced by β -receptor stimulation (terbutaline).¹³ In the present study tachycardia and decreased variability were more often recorded in terbutaline-treated patients, but fetal acidosis occurred seldom in this group. In nontreated patients tachycardia and decreased variability occurred significantly more often in cases of fetal acidosis. These results stress the value of these FHR changes as predictors of fetal asphyxia, even in preterm labor.

Late and early decelerations were rarely recorded; late decelerations were mostly associated with fetal acidosis. On the other hand, variable decelerations were often recorded both in group A (70%) and in group B (55%). These incidences are considerably larger than the 20 to 30% reported in normal term deliveries.¹² The high incidence of variable decelerations in preterm

Table 2. Types of Variable Decelerations

Type	Group A (28-33 weeks)			Group B (34-36 weeks)		
	N	Fetal acidosis	pH Ua (mean)	N	Fetal acidosis	pH Ua (mean)
Variable, uncomplicated	8	2	7.30	15		7.34
Variable + late component	3	3	7.14	4	1	7.23
Variable + overshoot	5	4	7.19	2		7.20

Fetal acidosis = pH < 7.25 at 5 cm and/or at full dilatation; Ua = umbilical artery.

Table 3. Depth of Variable Decelerations

Loss of beats	Group A (28–33 weeks)			Group B (34–36 weeks)		
	N	Fetal acidosis	pH Ua (mean)	N	Fetal acidosis	pH Ua (mean)
< 30	3		7.34	5		7.33
30–60	9	5	7.23	10		7.31
> 60	4	4	7.15	6	1	7.25

Fetal acidosis = pH < 7.25 at 5 cm and/or at full dilatation; Ua = umbilical artery.

infants has been linked to the relatively decreased amount of amniotic fluid, the decreased protective effect caused by less Wharton jelly in the cord of the preterm infant,¹¹ and a high rate of cord problems.²⁵ However, in the present study, cord problems occurred in 22 to 24%, a frequency not appreciably higher than in term deliveries. Cibils²⁶ described a correlation between ruptured membranes and variable decelerations; this could at least partly explain the high incidence of variable decelerations in the present study, as all patients had spontaneously or artificially ruptured membranes after a cervical dilatation of 4 cm.

Two types of complicated variable decelerations were observed, one with a late component, the other followed by a secondary overshoot acceleration. Variable decelerations with a late component are combined decelerations consisting of a variable component and then a late component. Four of 7 patients with this type of deceleration had a low fetal pH, and in 5 uterine activity was augmented with oxytocin infusion resulting in suspected overstimulation. Ingemarsson and colleagues¹⁸ suggested that this type of deceleration is associated with abnormal uterine activity.

A low fetal scalp pH was also common in the other type of complicated variable deceleration—a variable deceleration with an overshoot pattern. This type of deceleration has previously been associated with a high rate of subsequently depressed newborns.²⁷ Goodlin and Lowe²⁷ suggested that the secondary acceleration or overshoot pattern could reflect an immaturity of the FHR control. This concurred with the present authors' findings, as this type of deceleration was not recorded after week 34, and mostly in weeks 30 to 32 of gestation.

The rate of fetal acidosis (pH less than 7.25) in both groups is conspicuously high when given that the present material is composed only of selected preterm deliveries without prenatal complications. Fetal acidosis occurred significantly more often in patients delivered before week 34 than in those delivered in weeks 34 to 36 of gestation. Six of 8 patients with fetal acidosis at a cervical dilatation of 5 cm were delivered vaginally and 2 by cesarean section within 35 minutes after the acidotic pH value was obtained. Moreover, 7 of 12 with fetal acidosis at full dilatation had a normal pH value 40 minutes earlier. These findings show that preterm infants with acidosis in this study were not exposed to prolonged intrauterine asphyxia during a drawn-out delivery. However, obviously the fetal pH in these immature infants could change rapidly during vaginal delivery. This agrees with postnatal observations of preterm infants in whom even short hypoxic periods are followed within minutes by a falling pH.²⁸ From the present study it cannot be concluded that the fetal acidosis among these immature infants is primarily of respiratory or metabolic origin. This question requires further study as infants with a low pH secondary to respiratory acidosis might have a significantly different outcome than those with metabolic problems.

Most patients with a fetal scalp pH of less than 7.25 demonstrated ominous FHR changes during labor, but 6 of 12 group A patients had V-shaped variable decelerations of short duration with or without an overshoot pattern. Furthermore, among the smaller infants, fetal acidosis appeared in 5 of 9 patients with variable decelerations losing 30 to 60 beats per minute (Table 3). In infants in weeks 34 to 36 of gestation, V-shaped variable decelerations of short duration (less than 40

Table 4. Relationship Between Tachycardia, Decreased Variability, and Fetal Acidosis in Terbutaline-Treated and Nontreated Patients

	Nontreated (N = 38)			Terbutaline-treated (N = 23)		
	N	Fetal acidosis	P	N	Fetal acidosis	P
Tachycardia	14	9	.05	12	2	NS
Decreased variability	13	8	.01	11	4	NS

Fetal acidosis = pH < 7.25 at 5 cm and/or at full dilatation; NS = not significant.

Table 5. Acid-Base Status at 5 cm, Full Dilatation, and in Umbilical Artery

	Group A (28-33 weeks, N = 23)		Group B (34-36 weeks, N = 38)		P
	Mean pH ± 1 SD	Fetal acidosis (N)	Mean pH ± 1 SD	Fetal acidosis (N)	
5 cm dilatation	7.29 ± 0.07	6	7.33 ± 0.05	1	<.05 <.01
Full dilatation	7.27 ± 0.07	9	7.31 ± 0.06	3	<.05 <.05
Umbilical artery	7.25 ± 0.09	8	7.29 ± 0.06	1	<.05 <.01

Fetal acidosis = pH < 7.25 at 5 cm and/or at full dilatation, pH < 7.20 in umbilical artery.

seconds) and moderate beat loss (30 to 60 beats) were not associated with fetal acidosis; analogous findings are reported in term deliveries.²⁶ These results indicate that among tiny infants fetal acidosis can appear in connection with variable decelerations of innocent appearance. On the other hand, FHR changes considered classic for fetal distress, such as tachycardia, decreased variability, later decelerations, or variable decelerations with a late component, were strongly associated with fetal acidosis regardless of gestational age, which agrees with the findings of Paul²⁹ and Zanini and associates.¹¹

All patients in the present study underwent spontaneous or artificial membrane rupture after a cervical dilatation of 4 cm to make internal monitoring possible

(scalp electrode and scalp blood sampling); this might influence the results. Ruptured membranes are known to result in loss of cervical dilatation by forewater, increased uterine contractions, and increased head molding.³⁰ However, it is an open question whether these disadvantages are especially hazardous for the tiny infant. The risk must be weighed against the potential benefit from direct fetal monitoring during labor, as accurate FHR tracings by external methods are especially difficult to obtain in preterm labor.

In the assessment of the FHR tracing of the immature infant, the obstetrician must take the gestational age and the administration of β -receptor stimulators into account. Fetal acidosis can appear rapidly and frequently in patients delivered before week 34 of

Table 6. Obstetric Data of Patients with Fetal Acidosis

Case no.	Gesta-tional age (wk)	Mode of delivery	FHR			pH value			Apgar score [†]	Birth weight (g)	Remarks
			Baseline	Variability	Deceleration	At 5 cm*	At full*	Ua			
1	29	Cesarean	Normal	Silent pattern	Late	7.22	NA	7.18	8,9,9	1075	Abruptio placentae
2	29	Vaginal	Tachycardia	Decreased	Variable	7.20	7.32	7.28	9,10,10	1400	
3	30	Vaginal	Tachycardia	Normal	Variable + OS	7.33	7.19	7.11	7,9,10	1200	
4	30	Vaginal	Tachycardia	Decreased	Late	7.25	7.15	7.23	8,10,10	1220	
5	31	Vaginal	Tachycardia	Normal	Variable + OS	7.34	7.24	7.13	8,9,10	1610	
6	32	Vaginal	Tachycardia	Decreased	Variable + LC	7.25	7.20	7.17	2,7,9	2200	Febrile + over-stimulation?
7	32	Vaginal	Tachycardia	Decreased	Variable + OS	7.18	7.18	7.23	5,7,10	1400	Febrile
8	32	Cesarean	Tachycardia	Silent pattern	Late	7.12	NA	7.19	2,7,7	2380	
9	32	Vaginal	Normal	Decreased	Variable + LC	7.26	7.23	7.21	9,9,10	1550	Overstimulation?
10	33	Vaginal	Tachycardia	Decreased	Variable	7.36	7.22	7.16	9,10,10	1780	
11	33	Vaginal	Tachycardia	Silent pattern	Variable + LC	7.23	7.21	7.12	7,10,10	1770	Overstimulation?
12	33	Vaginal	Tachycardia	Normal	Variable + OS	7.18	7.20	7.26	7,8,8	1650	
13	35	Vaginal	Bradycardia	Decreased	Late	7.23	7.15	7.30	7,10,10	1920	SGA
14	36	Vaginal	Tachycardia	Decreased	Late	7.20	7.23	7.12	8,9,10	1850	Abruptio placentae + SGA
15	36	Vaginal (forceps)	Tachycardia	Decreased	Variable + LC	7.31	7.16	7.23	5,7,8	2450	

FHR = fetal heart rate; Ua = umbilical artery; NA = not assessed; OS = overshoot; LC = late component; SGA = small for gestational age.

* Stage of cervical dilatation.

† At 1, 5, and 10 minutes.

gestation. Infants born during weeks 34 to 36 seem to react more like term infants during labor.

Despite a high rate of fetal acidosis, the short-term fetal outcome was generally good, as judged from Apgar scores. These results do not justify expanding the use of cesarean section in a strictly selected group of patients in preterm deliveries without prenatal complications, as studied in the present investigation. A continuing long-term follow-up study of these preterm infants is in progress to clarify the question about the influence of the delivery on fetal outcome.

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INTRAPARTUM FETAL ACIDOSIS IN PRETERM INFANTS. A PROSPECTIVE STUDY IN
REGARD TO FETAL MONITORING AND LONG-TERM MORBIDITY

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ABSTRACT

Fetal heart rate (FHR) and fetal acid-base status were studied prospectively in 61 patients in preterm labor of unknown etiology. Neonatal data were analyzed and all surviving infants participated in a follow-up study for at least 2 years.

Ominous FHR patterns correlated well with fetal acidosis. Fetal acidosis occurred more often in weeks 28-33 than in weeks 34-36 ($p < 0.01$). Infants with fetal acidosis (pH less than 7.25 in scalp blood) had more neurological abnormalities in the neonatal period and a higher rate of neurodevelopmental disabilities at the follow-up than non-acidotic infants of the same gestational weeks. Due to the close association between ominous FHR-pattern and fetal acidosis and the potential adverse impact on fetal outcome a liberal attitude to Cesarean section at impending asphyxia in preterm deliveries is recommended.

INTRODUCTION

The impact of labor and mode of delivery on the fetal outcome in preterm deliveries is a controversial question in modern obstetrics. The preterm infant is vulnerable during delivery and studies of fetal monitoring have revealed high rates of fetal asphyxia in preterm vaginal deliveries (1, 2, 3).

Fetal asphyxia contributes to neonatal mortality and long-term morbidity. The significance of intrapartum fetal asphyxia in preterm infants is difficult to evaluate. A potential adverse effect may incorrectly be ascribed to prematurity as long as the presence or absence of acidosis is not precisely known (4).

Data on preterm infants in vaginal deliveries with continuous electronic fetal monitoring and repeated pH assessments were presented in a previous paper (3). The present study provides further data in regard to neonatal and long-term morbidity in acidotic and non-acidotic preterm infants.

MATERIAL AND METHODS

The study comprises 61 singleton infants in cephalic presentation, born before the 37th week of gestation in 1979 and 1980 at the Department of

Obstetrics and Gynecology, at the University Hospital in Lund. All deliveries within the area (the city of Lund and the surrounding countryside being the most densely populated area of Sweden) take place in the department. The obstetrical management has a high degree of homogeneity, since every delivery is managed only by the hospital staff obstetricians according to the prevailing Swedish medical system.

During pregnancy all mothers participated in the routine prenatal care at Maternal Health Care Centers. The following criteria were fulfilled: no additional maternal complications (no disease, signs of preeclampsia, anemia, or vaginal bleedings) and no additional fetal complications (biparietal diameter within 2 SD, normal symphysis-fundus distance). Gestational age was determined from data of the last menstrual period and by clinical and ultrasonic examination. Ultrasound examinations were performed in 56 of the 61 patients before admission to the hospital.

The reason for admission to the delivery ward was preterm labor of unknown etiology or premature rupture of the fetal membranes. During labor all mothers were monitored according to a standardized program. When the cervix was effaced and dilated at least 4 cm all tocolytic treatment was discontinued and electronic fetal monitoring via a fetal scalp electrode was started. Fetal scalp pH was measured both at 5 cm and at full dilatation. Acid-base status was measured in umbilical artery from the clamped cord (before the first breath).

All FHR recordings from 5 cm to full dilatation were visually assessed by either of the authors (I.I., M.W.) without any information about the outcome of the infant. The tracings were classified as either innocuous or ominous. Criteria for ominous FHR pattern were: a repetitive pattern of late decelerations or pronounced variable decelerations (> 40 sec duration and/or > 60 beats loss). Detailed information about the intrapartum period has been presented previously (3).

Immediately after birth the baby was placed in an Isolette radiant heat incubator. The Apgar scores were determined by the neonatologist (P.H., N.S.). After a 30-minute adaptation and observation period in the delivery ward the infant was transported to the adjacent Neonatal Intensive Care Unit (NICU).

Acid-base status was measured by capillary heel puncture technique at the age of 5, 30 and 60 minutes. The blood gases were analysed in an IL Autocal pH/Blood Gas Analyzer 613. The neonatal intensive care principles have been described previously (5).

All surviving infants were reexamined at 3, 7, 12 and 24 months with neurodevelopmental examination. The developmental performance was assessed according to the Denver Developmental Standard test with correction for conceptional age. Psychomotor developmental delay was designated as moderate (2-3 months) or severe (> 3 months).

In all infants who died autopsy was performed.

For statistical analysis the Student's t-test and χ^2 were applied. P-values above 0.05 were regarded as not significant.

RESULTS

At a cervical dilatation of 5 cm intrapartum fetal acidosis (scalp pH < 7.25) was found in eight patients. At full dilatation 12 patients had fetal acidosis, but seven of these had acidosis only at this stage of dilatation. Thus, in total 15 of 61 patients had intrapartum fetal acidosis. Fetal acidosis occurred more often in weeks 28-33 (52 %) than in weeks 34-36 (8 %) ($p < 0.01$). The correlation between FHR pattern and scalp pH is shown in Table I. Patients with ominous FHR pattern showed a positive correlation to fetal acidosis at a cervical dilatation of 5 cm, but not at full cervical dilatation, where four of seven patients with fetal acidosis demonstrated variable decelerations of innocent appearance. They all had a normal pH-value 40 min earlier at 5 cm dilatation indicating a terminal episode of asphyxia in these patients. Of the eight patients with fetal acidosis at a cervical dilatation of 5 cm two were delivered by Cesarean section. The remaining six patients were all vaginally delivered within 35 minutes after diagnosis of intrapartum fetal acidosis.

Fig. 1 shows the mean pH $\pm$ SEM in the acidotic and non-acidotic infants during labor, at birth and in the first hours of life. The difference in pH persisted until 30 minutes after birth, but at 60 minutes the difference had diminished. At birth and at 5 minutes of age the base deficit (BD) was larger in the acidotic than in the non-acidotic group of infants (Fig. 2). Thereafter a gradual decrease of the base deficit could be observed, and at 30 minutes of age no difference between the acidotic and non-acidotic infants could be demonstrated. The mean PO_2 and PCO_2 did not differ between the two studied groups.

Table II gives obstetrical characteristics of the acidotic and non-acidotic patients. In weeks 28-33 the two groups are similar in number (12 vs 11), mean birth weight and gestational age. In infants born in gesta-

Table I. Innocuous and ominous FHR-pattern in relation to the occurrence of fetal acidosis

Fetal Heart Rate Patterns	pH < 7.25 at 5 cm [†] n = 8	pH < 7.25 only at full [†] n = 7	Non-acidosis n = 46
Innocuous	1	4	40
Ominous	7 ^{xx}	3 ^{n.s.}	6 ^{n.s.}

[†]Stage of cervical dilatation xx = p < 0.01 n.s. = non-significant

Ominous: Repetative pattern of late or pronounced variable decelerations (> 40 sec duration and/or > 60 beats loss)

Table II. Obstetrical data and events

	28 - 33 wks		34 - 36 wks	
	acidosis	non-acidosis	acidosis	non-acidosis
Number	12	11	3	35
Gestational age (wks)	31.3 [±] 1.5	32.1 [±] 1.3	35.7 [±] 0.6	35.6 [±] 1.1
Birth weight (g)	1603 [±] 393	1690 [±] 243	2073 [±] 328	2343 [±] 357
Terbutaline treatment*	5	4	1	13
Corticosteroid prophylaxis	6	4	1	7
Mode of delivery				
Spontaneous vaginal	10	10	2	35
Forceps	-	1	1	-
Cesarean section	2	-	-	-

*Terbutaline infusion discontinued within 8 hours before delivery

Fig. 1. Mean pH in the acidotic (filled dots) and the non-acidotic infants (non-filled dots) during labor, at birth and in the first hour of life.

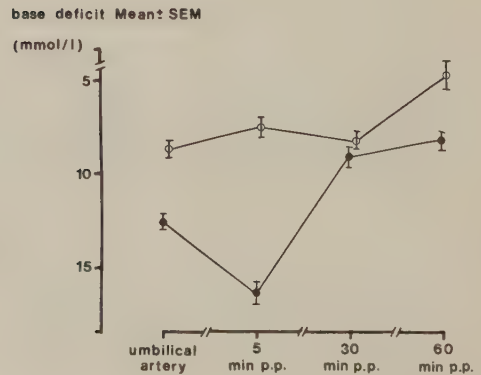
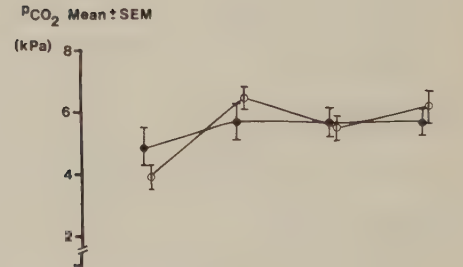
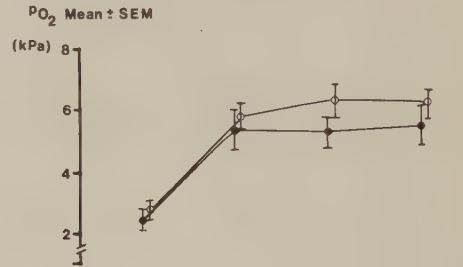
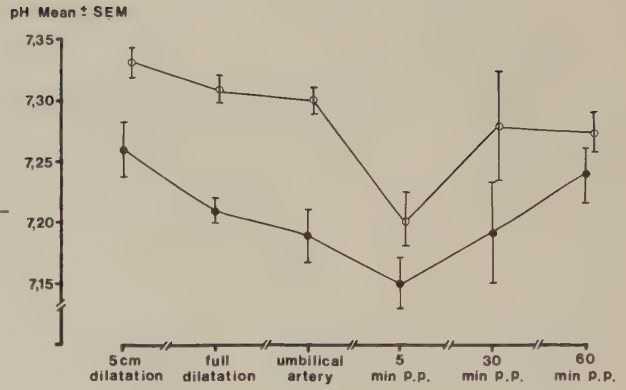


Fig. 2. Mean PO₂, PCO₂ and base deficit in the first hour of life. Symbols as in figure 1.

tional weeks 34-36 only three had fetal acidosis, and the mean birth weight was lower in these infants compared to non-acidotic infants of the same gestational age.

Neonatal data are presented in Table III. In infants born in weeks 28-33 a low one minute Apgar score (< 7) was more common in acidotic than in non-acidotic infants. The frequency of respiratory difficulties as IRDS, wet lung and recurrent apnea and the demand for assisted ventilation was higher in this group of patients. Furthermore, among infants with fetal acidosis neonatal neurological abnormalities such as hypotonia and seizures were observed more often.

Table III. Neonatal data and events

	28 - 33 wks		34 - 36 wks	
	acidosis	non-acidosis	acidosis	non-acidosis
Number	12	11	3	35
Boys/girls	6/6	5/6	0/3	21/14
Apgar score < 7 at 1 min	5	-	-	3
Respiratory difficulties				
IRDS	6	2	-	1
Wet lung	3	2	1	1
AR	1	1	-	2
<i>Total</i>	10	5	1	4
Assisted ventilation	11	4	1	5
Neurological abnormalities				
Hypotonia	2	1	-	-
Seizures	4	-	1	2
<i>Total</i>	6	1	1	2

IRDS = idiopathic respiratory distress syndrome

AR = respiratory insufficiency with recurrent apnea

Three infants died. Two infants had no signs of fetal distress at vaginal delivery but developed soon after birth severe respiratory insufficiency. They died within the first week of life. Autopsy showed hyaline membrane disease and intraventricular hemorrhage in one case and congenital heart malformation in the other. The third infant was born in the 33rd week of gestation with intrapartum acidosis i.e. scalp pH 7.18 at 5 cm and 7.20 at full cervical dilatation. He had severe IRDS and persistent ductus arteriosus and required assisted ventilation for 105 days. He died in sudden infant death syndrome at 6 months of age soon after discharge from NICU.

At 2 years of age 2 of 58 infants had cerebral palsy and another 4 infants moderate delay of psychomotor development. Table IV gives obstetrical and neonatal data of these infants. Of the two infants with cerebral palsy one was small for gestational age and the other was close to the lower level (-2 SD) in relation to gestational age. Ominous fetal heart rate patterns and fetal acidosis occurred significantly more often ($p < 0.05$, $p < 0.01$) in these infants compared to survivors with normal neurodevelopment. Patients with ominous fetal heart rate patterns showed a positive correlation to neurological disabilities at the follow-up study ($p < 0.05$).

DISCUSSION

The present study supports the hypothesis that ominous periodic fetal heart rate changes in preterm deliveries reliably predict intrapartum fetal acidosis (6, 7, 8, 9). The FHR baseline and variability were not assessed since these parameters are difficult to evaluate in immature fetuses (3) and especially after administration of β -receptor agonists (10).

A higher incidence of respiratory disorders with an increased requirement for assisted ventilation was found in infants with asphyxia during labor as also shown by others (6, 7, 11, 12). The importance of intrapartum fetal acidosis was also demonstrated by the fact that neurological abnormalities in the neonatal period were more common in acidotic compared to the non-acidotic infants.

The cerebral consequences of fetal asphyxia are related both to the maturity of the distressed fetus and the duration and severity of asphyxia (13). In the preterm infant asphyxia is associated with an increased fre-

Table IV. Obstetrical and neonatal data of infants with cerebral palsy or neurodevelopmental delay at 2 years of age

Gesta- tional age (wk)	FHR patterns	Scalp pH		Mode of delivery	Birth weight	Apgar score [†]	Neonatal diagnoses	Seizures	Assisted ventilation	Diagnoses
		At 5 cm*	At full*							
29	Ominous	7.22	NA	Cesarean	1075	8,9,9	Wet lung Septicemia	-	CPAP (4 d.)	Moderate psycho- motor delay (hypotonia of lower extremities)
29	Ominous	7.20	7.32	Vaginal	1400	9,10,10	IRDS	+	CPAP (10 d.)	Moderate psychomotor delay
32	Ominous	7.12	NA	Cesarean	2380	2,7,7	IRDS	+	IPPV (7 d.)	Moderate psycho- motor delay (hypotonia of lower extremities)
33	Innocuous	7.41	7.37	Vaginal	2080	10,10,10	-	-	-	Moderate psychomotor delay
35	Ominous	7.36	7.34	Vaginal	2120	7,8,10	Hypotonia	+	-	Hemiplegia
36	Ominous	7.20	7.23	Vaginal	1850	8,9,10	SCA	+	-	Hemiplegia

FHR = fetal heart rate

* Stage of cervical dilatation

† At 1, 5 and 10 minutes

NA = not assessed

CPAP = continuous positive airways pressure

IRDS = idiopathic respiratory distress syndrome

IPPV = intermittent positive airways pressure

SCA = small for gestational age

quency of intraventricular hemorrhages, due to the immature cerebral capillary bed, increased cerebral blood flow, elevated venous pressure and impairment of brain capillary endothelial (14, 15). In preterm infants intraventricular hemorrhages account for a major part of mortality and morbidity (14-16). In the present study seven children had intraventricular hemorrhages or seizures in the neonatal period. Of these two died and at the follow-up study four were handicapped.

In this investigation of the severity and duration of intrapartum acidosis it was found that most patients with fetal acidosis had only a moderate lowering of scalp pH. Only one patient had an intrapartum scalp pH of less than 7.15. At full dilatation fetal acidosis was found in 12 patients. Of these seven had normal pH at 5 cm dilatation. This may indicate fetal asphyxia of short duration, i.e. only during the last stage of labor. In contrast, eight patients had fetal acidosis already at 5 cm dilatation which probably implies a more severe and prolonged asphyxia. One of these infants died in the neonatal period. At the follow-up study one infant had hemiplegia, three showed psychomotor abnormalities and two of these infants had hypotonia of the lower extremities. The last finding is correlated with prolonged partial asphyxia in the fetal monkey (17). Thus, the infants with fetal acidosis at a cervical dilatation of 5 cm had the poorest outcome in our study population.

It is an open question whether an earlier obstetrical intervention may improve the outcome for these infants. Still, suggestive evidence has been presented by Bowes and associates 1980 that prompt operative intervention at ominous FHR pattern may be of benefit for the very low birth weight infant.

To summarize, there was a high incidence of intrapartum acidosis in infants born vaginally in the 28th-33rd week of gestation. Electronic FHR monitoring in these weeks of gestation appears to have a predictive value to fetal acidosis. Compared to non-acidotic infants preterm infants with intrapartum acidosis had a high rate of neurological abnormalities in the neonatal period and neurodevelopmental disabilities at 2 years of age. Our data suggest a high risk for acidosis in labor in immature infants. However, in our opinion the results should not be taken as a pretext for a general use of Cesarean section in these deliveries. Because of the close association between ominous fetal heart rate pattern, fetal acidosis and the potential adverse impact on fetal and neonatal outcome we would advocate liberal indications for Cesarean section at impending asphyxia in preterm deliveries.

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FETAL HEART RATE, LONG- AND SHORT-TERM VARIABILITY IN RELATION TO
ADVANCING GESTATIONAL AGE.
WITH SPECIAL REFERENCE TO FETAL MOVEMENTS

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ABSTRACT

Four normal pregnant women were monitored by abdominal electrocardiogram and registration of fetal movements weekly from the 25th week of gestation until term. The mean R-R interval, long-term variability and short-term variability were calculated by a computer system.

The mean R-R interval increased significantly ($p < 0.001$) with advancing gestational age. An increase of long-term and short-term variability could be demonstrated from the 25th - 30th to the 31st - 35th week of gestation, but not in later pregnancy.

Fetal movements occurred in the same frequency regardless gestational age. In fetal movement periods accelerations occurred in 21 per cent before the 31st week of gestation while in later gestation accelerations were recorded in 90 per cent of the fetal movements periods. On the other hand decelerations were associated with fetal movements in weeks 25 - 30 in a high rate (35 %) while in later gestation no such relationship could be observed.

The findings suggest that the decreased variability and the absence of accelerations or occurrence of decelerations during fetal movements in the 25th - 30th week of gestation can be falsely interpreted as a positive pathological non-stress test. Consequently, we propose that new criteria for interpretation of the fetal heart rate of the immature fetuses are required.

INTRODUCTION

In modern obstetric care with active management of high risk pregnancies and preterm deliveries the obstetrician is increasingly facing problems concerning immature fetuses. Electronic fetal monitoring is a major parameter in the evaluation of their condition. Until recent years experience of fetal monitoring has chiefly been gathered from term pregnancies. On the other hand our knowledge of fetal heart rate changes in immature fetuses has been rather limited.

In the last years several investigations of the developmental aspects on the cardiotocogram have been published (1, 2). With advancing gestational age the basal heart rate decreases (3) and the long-term and short-term variability increases (4). Before the 30th week of gestation the dominant alterations in fetal heart rate are decelerations. Later in

gestation accelerations predominate (1). This maturity related development often makes the assessment of the heart rate recording doubtful in the immature fetuses. A clear distinction between normal and pathological conditions is often difficult to obtain.

An additional major parameter of fetal well-being is the registration of fetal movements. This also changes with advancing gestational age (5, 6). The relationship between fetal movements and fetal heart rate form the basis of the non-stress test. However the relationship between fetal movements and fetal heart rate in immature fetuses is not well known. Thus the aim of the present investigation was to study the normal fetal physiology from the 25th week until term by means of fetal heart rate, long-term and short-term variability and to study their relationship to fetal movements.

PATIENTS AND METHODS

Four healthy women with an uneventful pregnancy participated in the present study. Gestational age was calculated from an ultrasonic examination performed in the 16th week of gestation.

With consent of the patients the fetal heart rate was monitored by abdominal electrocardiogram weekly from the 25th week of gestation until term. The records were of 40 min duration and were made between 11 a.m. and 3 p.m. All patients were monitored in a semi-recumbent position.

Hard ware

Figure 1 is a schematic illustration of the hard ware set up. The fetal heart rate was monitored by a Hewlett-Packard cardiocotograph (8030 A) and was written with a paper speed of 1 cm/min. At visually acceptable recordings the data were stored on a 4 channel analogue FM tape recorder (Hewlett Packard 3960). The output from the cardiocotograph to the FM

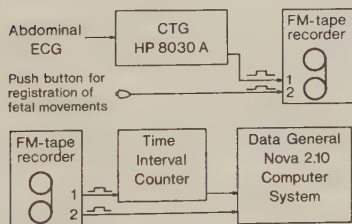


Fig. 1. Schematic figure of the hardware set up.

tape recorder was taken from the valid heart beat lamp indicator. The lamp lights up for approximately 120 ms for every valid heart beat or substitution made by the cardiotocograph itself. A substitution can only occur in the following two cases:

- a) if after two consecutive fetal pulses the next pulse is missing, one and only one substitution is made.
- b) if the fetal ECG is masked by the maternal ECG a substitution is made. A fetal ECG-complex will be masked if it occurs closer than 190 ms before the maternal R-wave or less than 75 ms thereafter.

The mothers were instructed to press a hand-held button as soon as they felt any fetal movements. This induced a pulse registered simultaneously with the heart beats. For identification of various parts of the registration, a DC-level was recorded simultaneously on the type recorder.

All registrations were transferred into the computer system. The distance in time between the pulses were converted into milliseconds for future calculations.

Soft-ware

Before any calculations were carried out the time intervals were corrected for known errors, as mentioned below. A window between 200 ms and 600 ms excluded artifacts due to missing pulses as well as short dropouts on tape due to defective magnetic coating.

In order to avoid the influence of accelerations or decelerations on R-R intervals and variability measurements one further exclusion was made by the program. The average time R-R interval was calculated and all intervals exceeding ± 10 per cent from this basal line were excluded. This was possible as the time interval distribution showed close resemblance to the normal distributions.

The computer calculated the mean heart rate interval, long-term variability and short-term variability for each sample of 128 successive intervals. The long-term variability was calculated as the standard deviation of the R-R intervals, and the short-term variability as the standard deviation of the interval differences for each 128 beats episode according to the criteria of Wheeler and associates (4).

For statistical comparisons the Student's t-test was used. P-values above 0.05 were regarded as not significant.

Accuracy of the system

An error analysis of the system is necessary in order to ensure that the overall systems accuracy is adequate for its purpose.

Firstly there is one unpredictable error, caused by the substitution process whenever a maternal ECG is blocking its fetal equivalent. In a previous study (7) the correlation coefficient between actual heart rate and abdominal fetal ECG was found to be 0.70 and 0.90 allowing 1 to 2 bpm error respectively.

Secondly, there are two predictive but correctable errors. Since we used two taperecorders, one recording information, and another replaying it to the time-interval counter connected to the computer system, a constant speed-difference between these will cause an error. Another error in the clockcircuit accuracy used by the time-interval counter will result in loss of accuracy. The magnitude of these two errors is proportional to the interval and was measured by a special setup. A high quality oscillator simulated the cardiotocograph, and the interval was measured before and after the time-interval counter. From these measurements, appropriate correction factors have been incorporated in the soft-ware manipulating the data.

In this study the effects of the accumulated errors, due to i.e. a constant minor error in the clock circuit, has little importance as no comparisons are made over several intervals at the time. The degrading of the measuring accuracy from the output of the cardiotocograph to the computer systems input is approximately 1 ms or less within one interval, i.e. if the fetal heart rate is 150 bpm (400 ms), the error of the interval is 0.25 %.

RESULTS

The material was divided into three groups in relation to gestational age; 25-30, 31-35 and 36-40 weeks of gestation. In each group visually acceptable recordings were obtained in 75, 70 and 85 per cent respectively, and were stored on the tape recorder. In total 70,800 R-R intervals were evaluated. As shown in Table I, the mean R-R interval increased significantly with advancing gestational age. An increase of long-term and short-term variability could be demonstrated from the 25th-30th to the 31st-35th week of gestation, but not in later pregnancy.

Table 1. Mean R-R intervals, long-term and short-term variability in relation to gestational age

	25-30 weeks		31-35 weeks		36-40 weeks		Significance		
	mean	± 1 SD	mean	± 1 SD	mean	± 1 SD	I v.s. II	I v.s. III	II v.s. III
R-R intervals (ms)	410	± 18	423	± 21	440	± 28	p < 0.001	p < 0.001	p < 0.001
Long-term variability*	9.2	± 3.9	12.9	± 4.8	12.3	± 5.7	p < 0.001	p < 0.005	N.S.
Short-term variability**	4.2	± 2.7	6.1	± 2.5	5.5	± 2.1	p < 0.001	p < 0.005	N.S.

* SD of R-R intervals

** SD of R-R interval differences

Figure 2 shows the distribution of interval differences in relation to the fetal heart rate (by means of R-R intervals in ms) in the three groups. An association between increasing heart rate and low variance was present in all groups. A comparison of corresponding R-R intervals in the groups revealed lower variance in the 25th-30th week than in the other two groups regardless of the heart rate frequency.

The frequency of fetal movements was the same in all three groups i.e. at 25th-30th weeks 6.2 ± 2.3 , at 31st-35th weeks 4.7 ± 3.0 and at 36th-40th weeks 5.7 ± 2.5 (mean $\pm$ SD per 10 minutes recording period).

The occurrence of accelerations (amplitude, more than 15 beats per minute; duration longer than 15 seconds) and decelerations (loss of more than 15 beats per minute; duration longer than 15 seconds) at fetal movements is presented in Table II. After the 30th week of gestation accelerations were concomitantly recorded in almost 90 % of the fetal movement periods. Before this gestational age acceleration occurred only in 21 % of the fetal movement periods. On the other hand, decelerations were associated with fetal movements in weeks 25-30 in 35 per cent while in later gestation no such relationship could be observed. In weeks 25-30 the fetal heart "response" during fetal movements showed either no alteration (44 %) or a deceleration (35 %).

Table 2. Incidences of accelerations and decelerations at fetal movements in relation to gestational age.

	25-30 weeks n = 114 per cent	31-35 weeks n = 239 per cent	36-40 weeks n = 190 per cent
Acceleration	17.5	54.8	59.0
Acceleration + deceleration	3.5	32.2	35.3
Deceleration	35.1	2.5	-

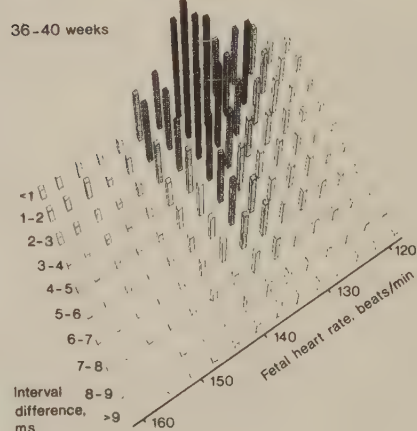
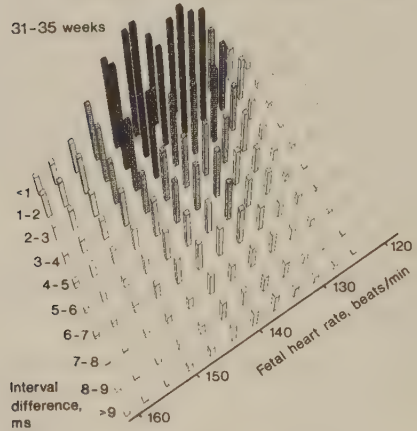
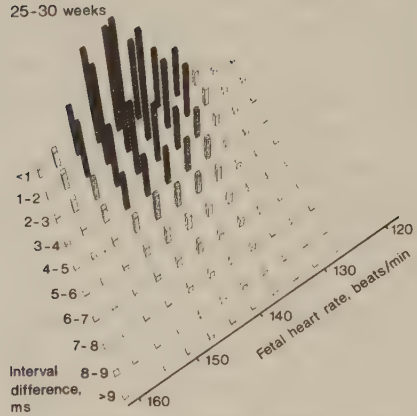


Fig. 2. Frequency distribution of interval differences in relation to subsequent R-R intervals of 10 ms; 360-369, 370-379.... 490-499. The R-R intervals are converted into and presented as beats per minute. With advancing gestational age a decrease of the heart rate and an increase of the variance of interval differences was observed.

DISCUSSION

The present findings confirm previous reports that fetal heart rate decreases and long-term and short-term variability increases in relation to advancing gestational age (4). These previous studies showed that the decrease in mean heart rate occurred mainly between the 24th and the 30th week of gestation. Thereafter only a reduction of the basal heart rate was observed. The mean heart rate did not fall after the 30th week since accelerations were prevailing over decelerations in the later part of gestation. In our study the basal heart rate also showed a decrease until term.

Several authors have claimed the low short-term variability of immature fetuses to be a function of the high heart rate in these infants (8, 9). Most indices for short-term variability calculation (10, 11) are correlated to heart frequency since the interval differences are related to the intervals producing it. In the present investigation the variance or the distribution of interval differences have been presented in relation to the fetal heart rate. As seen in figure 2 our findings confirm the statement that the higher the basal heart rate, the lower is the short-term variability. By comparison between corresponding R-R intervals in the three studied groups we also showed that a low variance occurs more often at lower heart rates in the 25th-30th week than in later gestation.

Our data indicate that the relation between fetal heart rate and fetal movements is altered with advancing gestational age. Before the 31st week decelerations are predominant, whereas later in gestation accelerations dominate. That the association between fetal movements and accelerations is depending upon the fetal maturation has previously been suggested (12) but not until recently been systematically investigated. Dawes and associates (1982) (2) demonstrated that from the 28th week of gestation clusterings of fetal movements occurred in periods of high variation, but not until a month later in the 32nd to the 33rd week the movements were combined with accelerations. In patients in the last trimester Timor-Tritsch and associates (1978) (13) demonstrated accelerations during 91 % of all fetal movements of 1-3 seconds duration. Conversely Dawes and associates (1981) (14) in normal pregnancies of 37-39 weeks showed that large accelerations (> 20 beats) were nearly always (98 %) associated with movements of the fetal trunk.

While this study was being evaluated, another study investigating fetal movements and fetal heart rate in relation to fetal maturity has been pub-

lished by Soroikin and colleagues (1982) (15). They compared two different groups of normal pregnant women in the 20th-22nd week and in the 28th-30th week of gestation. In the first group they found 1 % accelerations and 66 % decelerations during fetal movements. In the second group accelerations occurred in 36 % and decelerations in 22 %. Their results are thus in agreement with the present study despite different criteria and methods.

The changing heart response during fetal movements possibly indicates immaturity of the central fetal cardio regulatory mechanisms. It has been suggested that the brain coordinate the onset of accelerations at fetal movements (13). This is supported by the findings of Williams and associates (1976) (16) who showed that electrical stimulation of the fore brain in fetal lambs caused an increase in blood pressure and heart rate. Decelerations seem to be a "reflex-like" response at fetal movements in normal immature infants. Similar observations with brady-arrhythmias at various types of motoric stimuli are well-known from immature infants after birth (17), and is probably vagus mediated as atropine abolish the response (18).

The decreased variability and the absence of accelerations in fetuses in the 25th-30th week of gestation can result in a classical non-reactive pattern. Furthermore, the occurrence of decelerations during fetal movements in these weeks of gestation may be falsely interpreted as a pathological non-stress test. By comparison of non-stress test in high and low-risk patients Bishop (1981) (19) was unable to find any difference in the incidence of non-reactive patterns before the 30th week of gestation. Our results support his statement that "non-reactivity" is probably a function of gestational age rather than an indicator of fetal "jeopardy". Consequently we propose that new criteria for interpretation of the fetal heart rate of the immature fetus are required.

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